Integrating the Army Geospatial Enterprise: Synchronizing Geospatial-Intelligence to the Dismounted Soldier

by

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Army's Geospatial Architecture: delivering Geospatial-Intelligence of complex and urban terrain to the dismounted Soldier

by

James E. Richards

ABSTRACT

The Army's Geospatial Enterprise (AGE) has an emerging identity and value proposition arising from the need to synchronize geospatial information activities across the Army in order to deliver value to military decision makers. Recently, there have been significant efforts towards increasing the capability of the enterprise to create value for its diverse stakeholder base, ranging from the warfighter, to early stage research and development. The AGE has many architectural alternatives to consider as it embarks upon geospatial transformation within the Army, each of these alternatives must deliver value through an increasingly wide range of operating environments characterized by the uncertainty of both future technology and the evolution of future operations.

This research focuses on understanding how the Army's geospatial foundation data layers propagate through the battlefield and enable well informed tactical decisions. The goal of this investigation is to develop heuristics to guide the transformation efforts currently underway within the Army's Geospatial Enterprise. A set of surveys and informal interviews with individuals in the Army geospatial community inform the "as-is" enterprise architecture. A system dynamics (SD) model is developed to simulate the current state enterprise at the enterprise boundary, where the AGE delivers value to the warfighters at the tactical level. Potential future state architectures are developed, simulated in the SD model, and evaluated against a changing environment using Epoch-Era analysis.

The results do not attempt to optimize a desired future architecture for the AGE, but rather inform decision making early in enterprise development to assist the Army geospatial leadership to understand possible transformation trajectories. Several candidate architectures are developed and evaluated within the context of dynamic environmental conditions. Given lower resource availability, the best architectural choice is to focus on capturing the geospatial information obtained by Soldiers as they travel around the area of operations, learning about the terrain from experiences and interactions with local populations. As the level of funding increases, there is a significant jump in geospatial information if a geospatial sensor is deployed while at the same time synchronizing information dissemination and use. Aligning resources appropriately to a coordinated geospatial architectural approach is important to future military operations as new technologies continue to require increased geospatial information quality.

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I am deeply thankful to Dr. Donna Rhodes, my thesis advisor, for her outstanding academic mentorship. She patiently pulled me through research inexperience, guiding my work and providing me focus. In at least some small way, I humbly seek to apply, and perhaps contribute to, the work that she and colleagues in SEARI have developed over the course of several years.

In a broad sense, this work is the culmination of the past five years of my professional career. As a newly pinned captain, I arrived at the Topographic Engineering Center, at Fort Belvoir, VA, unknowing of the "geospatial" pathway that lay before me. My two years at TEC, now the Army Geospatial Center, were extremely rewarding, as I worked on the Buckeye Project, a mapping sensor system. Following this assignment, I requested to command the Topographic training company, continuing to work with many of the same individuals as I had at TEC.

Through these assignments I became well acquainted with the Army geospatial community, an informally connected, tightly knit group of professionals from the military, government and commercial sectors. So many of them kindly spent numerous hours answering my countless questions, while patiently putting up with my ignorance. Though there are so many that have contributed to my work, I am particularly grateful to Mike Powers, Mike Harper and Jason Feser for their thoughts on this topic.

I would thank my parents for their many years of support and encouragement. My wife, Cy, and three boys, Josh, Coby and Mitch have been an unending source of inspiration over the past 18 months, it is to them that I owe the biggest debt of thanks. They have put up with late nights and my absent mindedness, enabling me to finish my studies and this research. They have been an amazing source of unending love and support.

Finally, I write these words of reflection from my son's bedside in the Intensive Care Unit of Boston's Children's Hospital. He is a wonderful little boy with big brown eyes and a deep soul, even while his special needs make him susceptible to troubling ailments. His courage and determination far outstrip my own and he has persevered through much. He has shown me that, through Christ, it is in our weakness that we can be made strong.

As an active duty Army officer, I affirm that the views, analyses, and conclusions expressed in this document are mine and do not reflect the official policy or position of the United States Army, the Department of Defense, or the United States Government.

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1 Introduction

In this thesis, a general framework for the United States Army Geospatial Enterprise (AGE) is developed and applied to inform the design of the geospatial system. The focus is on value delivery by the Geospatial Foundation (GF) layer at the edge of the enterprise, at the Brigade level and below. This chapter describes the research motivation, gives the problem statement, and provides an overview of the technical approach and methods employed.

1.1 Research Motivation

One mission of the Army Corps of Engineers is to provide topographic support to maneuver operations. Typically, this data is used for two purposes, either as a part of the deliberate planning cycle of a commander and his staff, or as a reference for situational awareness of a Soldier operating in the battlespace during mission execution. The sources of geospatial data vary widely, from spaced based satellite systems, to contextual data obtained from a dismounted foot patrol. The system that unites these data producers and data consumers (some of whom are the same individuals, separated in time) has been evolving quickly since the start of the Global War on Terrorism. In many of the current operations, the size of the enemy has decreased from kilometers of linear frontage to a single individual moving quickly in complex and urban terrain. Enemy tactics in the Contemporary Operating Environment (COE) have taken on asymmetric characteristics, where the weaker actor moves in and out of the civilian population making them more difficult to identify and attack. With these changes, the spatial and temporal resolution needs of mission planners and operating Soldiers has increased as well. These demands continue to stress the geospatial information system in manpower, equipment, technology and information quality requirements.

The Army has started to adapt to the new environment by changing access to topographic support through modular transformation. Within the legacy Army structure, topographic support would flow from Corps level topographic battalions, down through a hierarchical structure to the users at the battalion level and below. In the newly established modular Army structure, the topographic battalions are disbanded and the topographic assets are attached to brigade headquarters in order to better equip these smaller, "modular" units to operate independently. With this new structure, there arises a difficulty to synchronize geospatial operations, and to leverage economies of scale for data production and storage. Also, the new structure presents many opportunities for increased dissemination of data to lower levels of the force structure, as well as leveraging the collection activities of the Soldiers themselves at those lower levels and back up each echelon, similar in concept to the Army Deputy Chief of Staff for Intelligence program "Every Soldier a Sensor" (ESS or ES2.) But the current enterprise leaves much of this valuable information out of the geospatial foundation layer. Routinely, information is lost within the enterprise, Soldiers are left saying, "someone knew that the terrain had changed, but my map did not show the update, so I had no idea."

1.2 Problem Statement and Objective

It is the goal of this research to illuminate the effects of design decisions of the Army geospatial enterprise upon the lowest echelons of the force. The goal has three parts: 1) to determine the impact of the geospatial system on "tactical decisions makers" at the brigade level and below 2) to determine the most efficient Army Geospatial Enterprise design for, collection, storage, analysis, and dissemination, and 3) to determine the future state architecture that the enterprise should pursue.

The objective of this research is to investigate how Enterprise Architecting (EA) and Epoch-Era thinking may better inform Army Geospatial Enterprise development. This thesis seeks to provide a structured approach to holistic thinking for AGE decision makers to understand the current state of the enterprise, as well as the impact a series of architectural changes might have on enterprise performance. These candidate future state architectures can then be compared using Epoch-Era analysis to determine value delivery over several possible future sets of environmental conditions.

1.3 Overview of Technical Approach

Two methods of data collection will be used to determine the requirements and the utility of geospatial data. A survey of MOS 21U and 215D (geospatial engineer Soldiers) conducted in conjunction with interviews of community leaders located at the Army Geospatial Center (Fort Belvoir, VA). Also, literature reviews of the Army Engineer School, Army Maneuver Center, Army Intelligence Center, National Geospatial Intelligence Agency (NGA) and Joint Staff publications will provide insight into the needs of each of these stakeholders.

System Dynamics (SD) and Enterprise Architecture (EA) methods are used to formulate several "future state" architectural alternatives for the enterprise which maximize the utility of geospatial information to the users. Then, these options are evaluated within a value creation framework over a changing set of environmental conditions. The future state alternatives seek to achieve a value robust enterprise which "will continue to perform well in the face of changing operational environments and a dynamic context" (Ross and Rhodes 2008). The value will be defined by the preference attributes of the enterprise stakeholders, and the environment will include both "upstream" factors such as technology and resources, as well as "downstream" factors such as the tactical operating environment of deployed military forces.

The choice of low fidelity models aimed at a holistic picture of the Army's Geospatial Enterprise is intentional, though not without drawbacks. Several aggregations of stakeholder preferences and detail simplification were necessary, although the high level view decreases the chances of sub- optimization of components of the enterprise. It encompasses both "doing the right things" *and* "doing *those* things right." The focus of this research is to determine what the right things are, enlightening the design efforts of the architecture currently ongoing within the Army Geospatial Center (AGC) and at other locations. The most leverage that management has within the system design process is at the beginning of the process, within concept development. As high level decisions are made, typically in the absence of detailed knowledge of the impact of the decisions, lifecycle costs are quickly committed sometimes toward a faulty concept. These relatively uninformed decisions determine much of the utility of the system to include system performance within an evolving environment, changing both tactical applications, as well as the technological environment the system operates within. Therefore, the need to provide as much knowledge about the effects of design decisions as early as possible in the architecting effort is critical.

Research Approach:

1) Identify the current geospatial information needs of battalion level commanders and their staff
2) Identify the current geospatial information needs of dismounted Soldiers operating in complex and urban terrain
3) Assess the information sources and interactions within the Army geospatial system needed to meet the data requirements of the battalion level Tactical Operations Center (TOC) and subordinate units
4) Analyze current approaches and determine the costs and relative value delivered by each method
5) Determine the impact of the above approaches on the Army DOTLMPF (Doctrine, Organizations, Training, Leader Development, Materiel, Personnel and Facilities)
6) Evaluate potential future state AGE architecture performance against changing environmental conditions

1.4 Thesis Organization

Chapter 2 provides a background discussion of the history of Army geospatial operations and an introduction to the Army Geospatial Enterprise delineating enterprise boundaries. This is followed by the methods and foundation of the approach for this research. Chapter 2 also briefly defines the key terms used throughout the rest of the thesis.

Chapter 3 describes the current state of the Army Geospatial Enterprise. A value-creation framework is combined with eight views into the enterprise architecture to enable a complete view of the AGE. The chapter begins with value identification and an extensive stakeholder analysis for the AGE. This analysis is the foundation for the "needs to goals" framework, which takes the outcome of the stakeholder analysis and produces goals that the enterprise must achieve to be successful across the entire set of stakeholders. The value proposition is defined in its current state. And finally the eight views of enterprise architectures are used to define the current state value delivery. The results from an extensive survey of the Army Geospatial Community are applied to create and validate the value creation framework. Finally a system dynamics model of the AGE boundary is introduced and evaluated to provide a current state baseline. The model provides the basis for future state analysis in chapter four.

Chapter 4 develops a value driven design for potential future states of the Army Geospatial Enterprise. Value driven design evaluates the possible design variables for the enterprise, the "knobs" that enterprise leadership can control with the attributes of the stakeholders. This allows further analysis and study to focus alternatives on the areas that have the greatest chance of creating value. This approach increases the creativity within the future state architecture alternatives. Three future state alternatives are then modeled in more detail using the system dynamics AGE boundary model developed in chapter three. The results of this analysis are used to draw conclusions for enterprise transformation efforts.

Chapter 5 concludes the discussion with a set of heuristics for transforming the Army Geospatial Enterprise based on the current state and future state alternatives investigated and modeled in chapters three and four. The heuristics help to focus the architecture efforts of AGE organizations and help prioritize the limited resources within the Army Geospatial community. The chapter ends with a discussion of future work within the research area of the AGE.

The figure below summarizes the general approach of the research and how the approach fits into the organization of the thesis. As the figure demonstrates, there are several points which lend themselves to iterations of the approach in order to yield better fidelity of the model as well as a more complete picture of the values of the stakeholders.

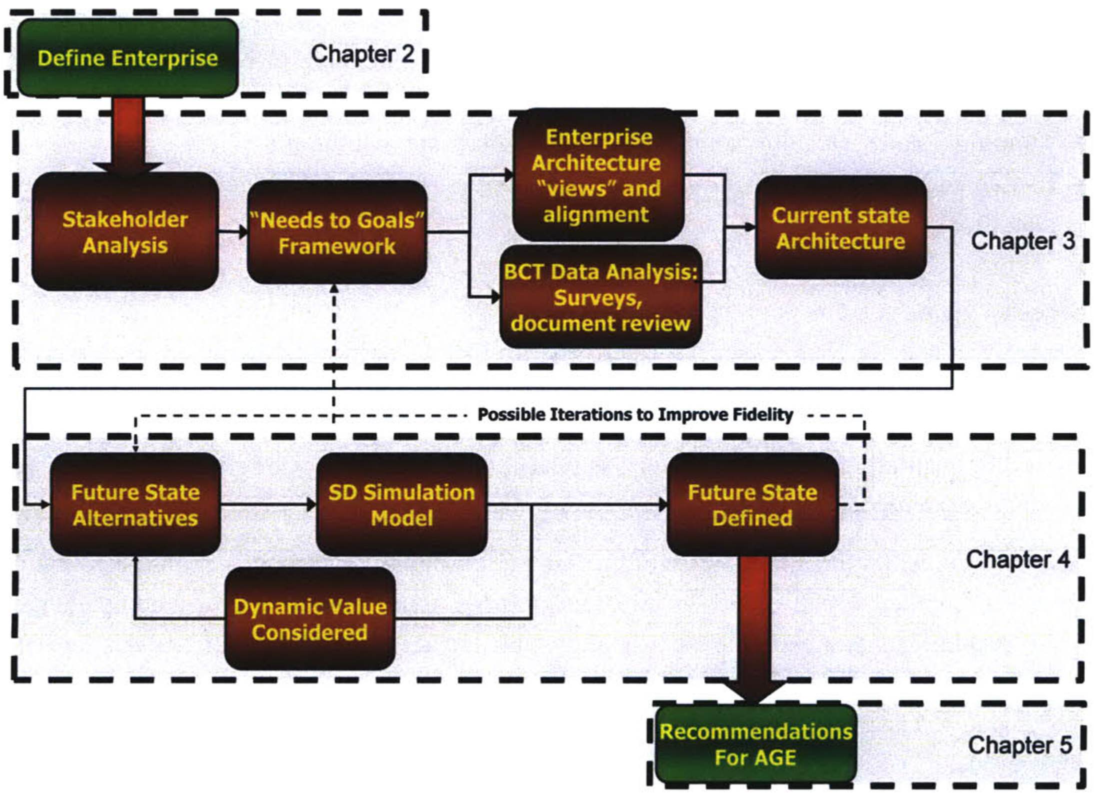


Figure 1-1: Thesis Organization

2 Background

This chapter provides a background discussion of the history of Army geospatial operations. It provides an introduction to the Army Geospatial Enterprise delineating enterprise boundaries. This is followed by the methods and foundation of the approach for this research. Chapter 2 also provides a brief overview of the key terms used throughout the rest of the thesis.

2.1 Historical Perspective on Army Geospatial Operations

Throughout history terrain has played a defining role in the outcome of armed conflict. Clever exploitation of the terrain allows an inferior force to defeat a more powerful enemy, while ignorance of the battlefield effects of terrain quickly nullify combat power. Sun Tzu states in the *Art of War*, "If you know the enemy and know yourself, your victory will not stand in doubt; if you know Heaven [weather] and know Earth [terrain], you may make your victory complete" (Sun Tzu 1910)

Clausewitz, another famous military thinker, observes "Finally, the general unreliability of all information presents a special problem in war: all action takes place, so to speak, in a kind of twilight, which, like fog or moonlight, often tends to make things seem grotesque and larger than they really are. Whatever is hidden from full view in this feeble light has to be guessed at by talent, or simply left to chance. So once again for lack of objective knowledge one has to trust to talent or to luck" (Clausewitz 1976). The Army Geospatial Enterprise seeks to increase understanding surrounding the uncertainty of the terrain so often hidden from view.

The origin of the topographic field within the Army Corps of Engineers began with Gen. Robert Erskin, the first topographer of the Army during the Revolutionary War. Following the Revolution, Army topographers conducted exploration and mapping missions of the newly added western territory of the United States. The Army Map Service (AMS) continued the mapping tradition, providing maps for operations around the world, including hundreds of millions of map sheets in support of World War II (Escape Maps 2010). In 1972, a major reorganization of many Department of Defense cartographic agencies combined them into the Defense Mapping Agency. Again, reorganization transformed the DMA into the National Imagery and Mapping Agency (NIMA), combining imagery work with traditional cartographic mapping to gain efficiencies between the two efforts. The current organization is the National Geospatial-Intelligence Agency (NGA.) Throughout these reorganizations the Army retained geospatial capability, both in the Corps of Engineers and the Intelligence branches.

Since the early 1990s, digital information systems have revolutionized map production, storage and dissemination industries. Geographic Information Systems (GIS) proliferate the daily lives of millions of people though handheld devices and the Internet. The Army continues to incorporate emerging technologies into geospatial operations. Some of these technologies include sensors, automated extraction and terrain reasoning algorithms, and interaction with modeling simulation and training. One of the latest efforts is the way in which geospatial information support network centric operations.

2.2 Army Geospatial Introduction

The Army Geospatial Enterprise delivers information about the environment (battlespace) to decision makers on the battlefield. The enterprise consists of "the personnel, units, systems, platforms, and processes that use, produce, store or manage geospatial data which can potentially be shared for operational purposes" (TRADOC Capability Manager Geospatial 2009). The enterprise resides inside the Army Battle Command (BC) enterprise, but interacts with all of the warfighting functions. The enterprise uses ground based and airborne sensors, including technical and human methods to understand the terrain. The enterprise analyzes the terrain through human analysts as well as by means of some use of automated terrain reasoning algorithms. Much of the enterprise resides in an information technology infrastructure of networks and databases at many echelons and locations around the world. The enterprise boundaries are critical to establish the scope of the enterprise and thereby the identity of the stakeholders. For the purpose of this analysis the enterprise boundary is defined by the entities that the Army Geospatial Governance Board (GGB) has direct control over. The enterprise is directly responsible for the "mental models" of terrain that enable informed tactical decision making. This innovative definition allows a slightly broader enterprise definition than previously utilized by others within the geospatial community. The problem with drawing the boundary before the cognitive domain of the tactical decision maker is that it risks the mentality that the purpose of the AGE is to produce "cool" products, independent of whether those products truly impact the understanding of the Soldiers operating in the battlespace.

The question of who should have access to what information is not trivial. It is a significant architectural design issue. The logical conclusion of a network centric warfare purist might entail all information being available to all nodes of the network instantaneously. But this may not be the most beneficial architecture operationally. The type and quantity of geospatial information made available is tempered by the cognitive limitations of the human battlefield decision makers.

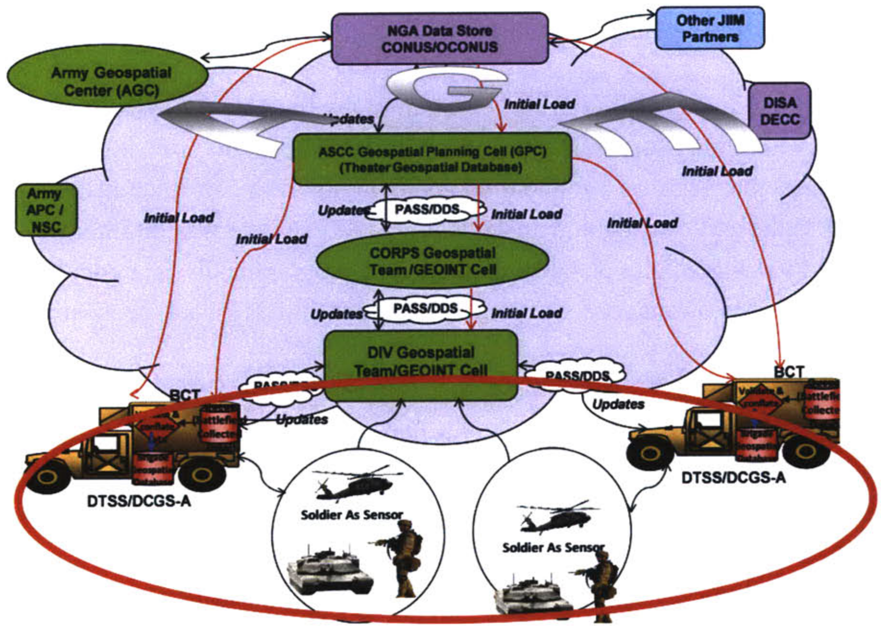


Figure 2-1: Enterprise Boundaries, adapted from (TRADOC Capability Manager Geospatial 2009)

2.3 Definitions

In order to provide a common ground for discussion, several key terms are defined as they are used throughout the thesis.

a. Information: 1. an observation that is placed into some meaningful context (Alberts, et al. 2001). The context that makes the observations meaningful must be provided or learned and comes from many sources. In order for information to communicate meaning properly, the sender and recipient must have a common set of "constraints" which make up a shared context. Most commonly the military use of information has context provided by formal or informal military training, creating the "common ground" allowing information to be useful (Devlin 2001). 2. "Facts, data, or instructions in any medium or form" (JP 1-02) 3. "The meaning that a human assigns to data by means of the known conventions used in their representation" (JP 3-13.1)

b. Intelligence: "1. The product resulting from the collection, processing, integration, analysis, evaluation, and interpretation of available information concerning foreign countries or areas. 2. Information and knowledge about an adversary obtained through observation, investigation, analysis, or understanding." (JP 1-02) Intelligence is a subset of information. Some of the Army's geospatial information is intelligence, specifically GEOINT. Some geospatial information can span upstream of intelligence, that is to say information collected from the environment has not been processed (or only processed to some degree), integrated, analyzed, evaluated or interpreted. Also, some portion of geospatial information may span past intelligence into information for operations, such as operational graphics including key terrain or some other terrain information, such as friendly obstacle emplacement or avenues of approach.

c. Geospatial intelligence (GEOINT): "Geospatial intelligence (GEOINT) supports joint forces in their ability to rapidly respond to threats around the world by providing geo-referenced visual and data products that serve as a foundation and common frame of reference for any joint operation. GEOINT is the exploitation and analysis of imagery and geospatial information to describe, assess, and visually depict physical features and geographically referenced activities on the Earth. GEOINT consists of imagery, imagery intelligence (IMINT), and geospatial information." (JP 1-02)

d. Geospatial information: is information (as defined above) "that identifies the geographic location and characteristics of natural or constructed features and boundaries on the Earth, including: statistical data and information derived from, among other things, remote sensing, mapping, and surveying technologies; and mapping, charting, geodetic data and related products." (TRADOC Capability Manager Geospatial 2009) Army geospatial information can be classified into two primary groups, the geospatial foundation data (GF) and the layers of information that reside on top of the foundation layer.
Geospatial information can also be classified into two categories based on who is generating or using the information. If the information is generated or used at the strategic level of war, this is termed "national" information. If the information is generated or used at the tactical level of war, this is "tactical" information. Geospatial data is used synonymously with geospatial information (within this thesis), though there may be an implication that "data" refer to digitally stored information which has not be processed or analyzed.

e. Geospatial Foundation Data (GF): "results from storing, managing, and collecting all operationally relevant spatial and temporal data in standardized, distributed geospatial databases which then enable sharing, correlation, and fusing of data across the Army, from all six War Fighting Functions (WFF.) GF data is collected from NGA, JIIM partners and commercial sources. The GF data will be replicated from Army GPCs to the Corps, Division, and BCTs to support the building of the COP. WFF geo-enabled applications will build data layers upon the GF." (TRADOC Capability Manager Geospatial 2009) The geospatial foundation data layer is a subset of the geospatial information available to the brigade.

f. Enterprise Architecture (EA): "applying holistic thinking to conceptually design, evaluate and select a preferred structure for a future state enterprise to realize its value proposition and desired behaviors" (Rhodes, Ross and Nightingale 2009). EA seeks to understand the complex interactions of the various perspectives of the enterprise and leverage these interactions to deliver greater value for the stakeholders of the enterprise.

g. Information quality: in essence, the usefulness of the information. Alberts et al. (2002) identify five dimensions of information quality: completeness, correctness, currency, accuracy or level of precision, and consistency. Another term for quality is the "richness" of the information. The value of information is a function of quality and frequency of use (or equivalently, richness and reach). Together quality and frequency of use determine the value of the information to the enterprise.

2.4 Defining AGE Value

Information that creates sound tactical knowledge in the mind of the planning staff and operators is the overall goal of the enterprise. The knowledge of the terrain that enables the most effective tactical decisions is conveyed through the geospatial foundation layer and additional layers (or overlays) contributed from across the Warfighting Functions (WFFs.) In order to properly deal with the concepts of data, information and knowledge, each of these will be defined and applied to the Army Geospatial example.

2.4.1 Discussion of Geospatial Information

A brief discussion of a theoretical foundation of information is necessary in order to understand how geospatial information flows within the enterprise. Some of the foundational terms are defined above in Section 2.3, but a short description here, in order to build common perspective, is helpful. Within the geospatial context, the information domain is an abstraction layer between the physical world and the cognitive world. It consists of data at its lowest level through natural language at the highest level.

The lowest level of the foundation data is the elevation data. This data set provides the geometry of the battlefield, a fundamental characteristic of the terrain. Once the geometry of the terrain is known, at least with some degree of fidelity, the characteristics of that surface may be of interest., for example, the color and surface properties, or image of the terrain. Traditional topographic maps capture both of these characteristics as elevation contours and features, such as forests, roads, water, etc. This type of information usually lasts for months, given that the environment does not change drastically during that time, for example, kinetic operations in urban terrain might quickly and significantly change the landscape making even Tier One data obsolete.

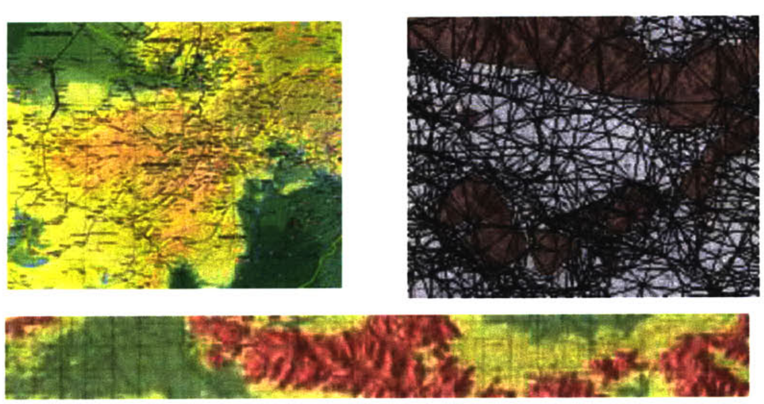


Figure 2-2: Examples of Tier One Geospatial Information (adapted from Powers 2010)

The mission focused information, Tier Two, is information that has been tailored to the type of missions being conducted. These consist of typical terrain products such as line of sight products, view sheds, and route studies. Their usefulness extends over a set of tactical needs on a given set of terrain, but would change as the mission type changes, such as a transition from counter insurgency operations, to peace keeping operations for example.

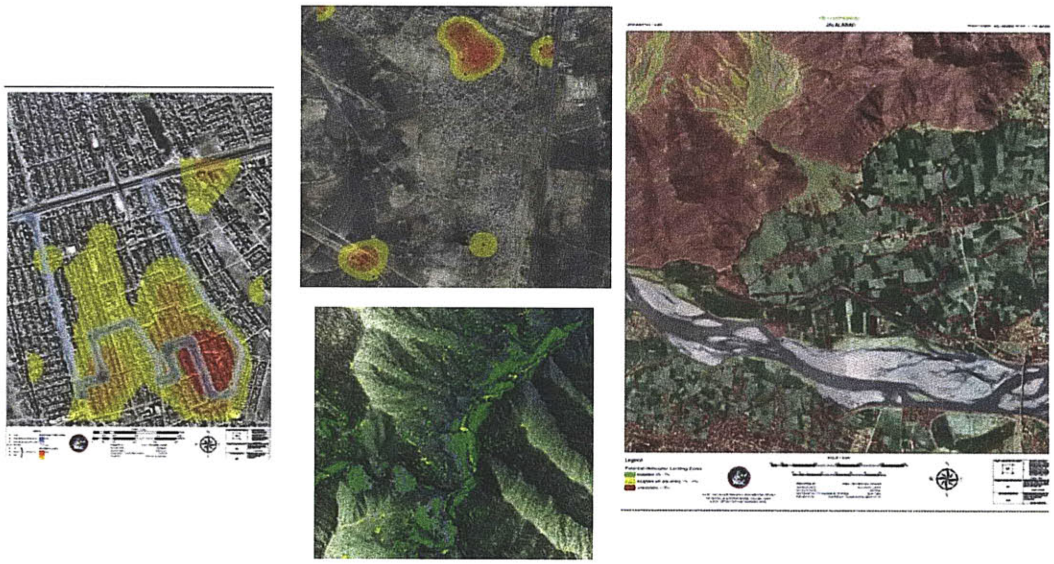


Figure 2-3: Examples of Tier Two Geospatial Information (Hoops 2010)

The control graphic information, Tier Three, is specific to the mission and exact operation because it contains very specific command and control information. It may consist of information such as which route to take to action on a target or which covered and concealed position to use prior to an assault. This information is developed during the planning phase of a mission. It may be deliberate, such as formalized control graphics, or hasty, such as a squad leader marking key terrain on an overlay. Even small changes to the mission can change the usefulness or content of Tier Three information instantaneously.

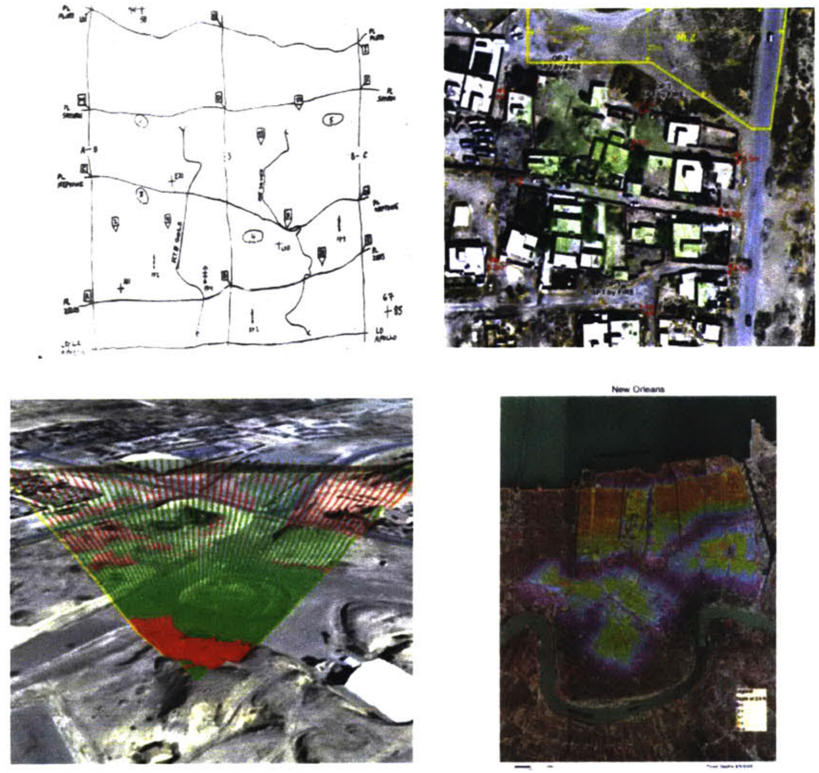


Figure 2-4: Examples of Tier Three Geospatial Information (adapted from Hoops 2010)

Table 2-1: Geospatial Information Taxonomy (adapted from Powers 2010)

Tier	Purpose	Typical Shelf life
Tier 3: Layers in control graphics	Defines actionable mission plan	hours - days
Tier 2: Mission focused	Provides mission specific context	days - months
Tier 1: space and time organized	Foundation for planning and operations	months - years

With the combination of the value stream map and the Tiers of geospatial information, a form of geospatial information domain hierarchy appears. The goal of the geospatial value stream is to provide the information necessary to make good decisions on the battlefield. The array of decisions that are routinely made is very large; therefore the breadth of geospatial information and the versatility of the information provided to the decision maker must be large as well. This breadth of information can be thought of as a portfolio of information along a spectrum from the physical to the cognitive domains.

In a general sense, information is absolutely necessary for successful military operations. When Soldiers arrive in theater they have received briefings about the mission, enemy forces, terrain, friendly troops, time scales for the mission and civilian considerations (METT-TC) for the Area of Operations. As they deploy, they have no experiential knowledge of the AO. Their "green books", literally a green common issued note book that most leaders carry, are empty. The leaders and Soldiers have not experienced the battle space, so that their cumulative understanding of the terrain based upon operations is zero. As Soldiers begin operations, they capture lessons learned, intelligence and other information into their green books. Much of their experience is terrain information. It may or may not have direct intelligence value at the time, but this collective knowledge of the environment both in the green book and in the Soldiers memory and experience, can provide critical information for others operating on the same battlespace.

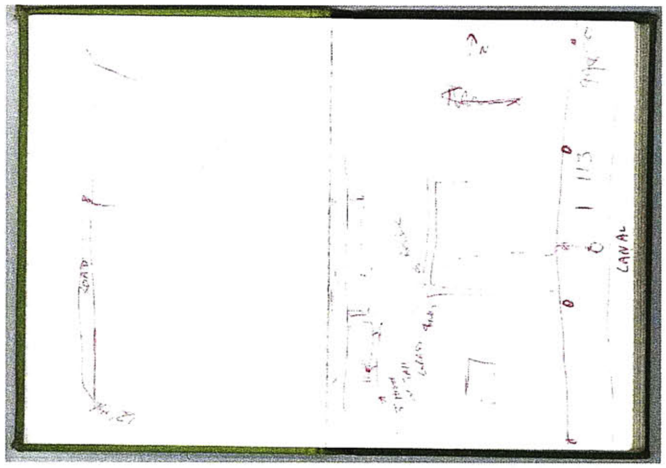


Figure 2-5: Example of "Green book" Soldier Identified Geospatial Information

The Army Geospatial Enterprise aims to increase the ability to harness the untapped information already inside the enterprise. This is achieved by bringing more of the Tier One, Two and Three information as identified above to more individuals operating on the battlefield. It also is achieved by providing a common geospatial understanding by way of the Common Operating Picture (COP) to allow collaboration and synchronization in planning and operations. These efforts work to make information already in the enterprise more effective and more available. The Army Geospatial Enterprise also works to bring new information previously undiscovered into the enterprise. This is done by providing new ways to sense the terrain, through airborne and terrestrial methods, to increase the total amount of terrain information in the enterprise, thereby adding to the Tier One, Two and Three information that already exists.

2.4.2 Discussion of Net Centric Warfare

"NCW is a set of warfighting concepts designed to create and leverage information." (D. S. Alberts 2002) The Army Geospatial Enterprise deals primarily with information, therefore a brief discussion of network centric warfare is appropriate. Network centric warfare relies on the premise that there is a military advantage to have information superiority over one's enemy. Figure 2-6 is the depiction from Alberts et al (2002) of the three domains of network centric warfare and how the domains interact. The following discussion of domains develops the three domain construct specifically for geospatial information.

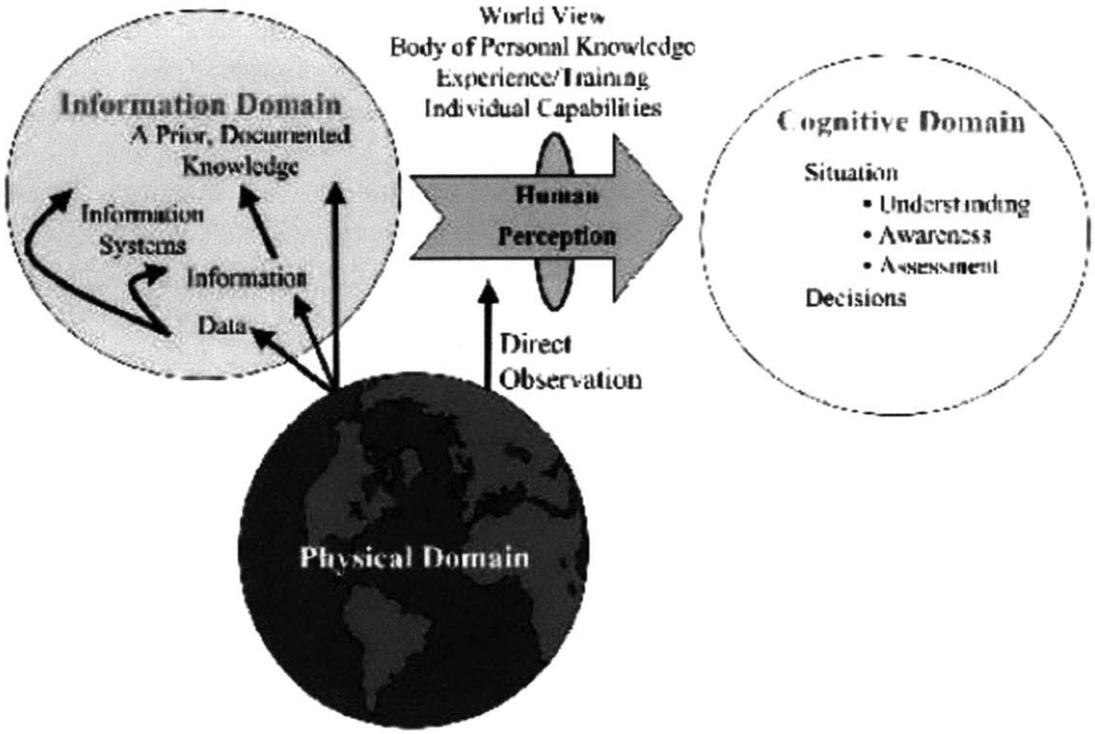


Figure 2-6: The Domains of Network Centric Operations (Alberts, et al. 2001)

The physical domain of the AGE is relatively straight forward. It is the physical terrain upon which Army operations take place. The type of terrain significantly impacts the nature of the operations. Open and rolling terrain in arid plains or desert lends itself to one set of tactics, while operations in complex urban terrain require different techniques. The enemy will most likely seek out the type of terrain that garners them as much tactical advantage as possible. Therefore, one can expect that future military operations will occur across the spectrum of terrain types, this will be discussed more completely in section 2.5.6.

The information domain typically resides between the physical domain and the cognitive domain. It consists of a continuum, or hierarchy, beginning closest to the physical domain and ending at the edge of the cognitive domain. An example of the lowest level of information is "raw data" that is directly from a sensor. The highest level of the information domain is natural language. This is a description of terrain which a direct observer might have. A form of natural language is typically used in reporting, though it make be augmented with other levels of the information domain as well.

The information hierarchy described in Table 2-1 and the model given in Figure 2-6 can be mapped together and laid against the value stream map of the enterprise. This is done in Figure 2-12.

The cognitive domain of the AGE occurs in the minds of the AGE personnel throughout the value stream as well as in the tactical decision makers at the enterprise boundary. The cognitive activities include creativity, assessment, awareness, understanding, and decisions. These activities occur in the context, or common ground, of training, culture, experience and personal knowledge.

2.5 Army Geospatial Enterprise Description

The enterprise that this research seeks to analyze is the US Army's geospatial enterprise. This can be thought of as how the Army understands the environment of the battlespace. The environment would typically include terrain and weather effects, though terrain will be the primary focus of this analysis.

> "Organizing Principle: A comprehensive framework for systematically exploiting and sharing geospatial information and services to enable Army Full Spectrum Operations to be conducted with maximum situational awareness and understanding. Specifically, it is comprised of the people, organizations, technologies, policies, doctrine, and materiel solutions involved in the acquisition of geospatial data, the production of geospatial information, and related discovery, integration, and distribution services. At its core, the AGE is a set of databases within a supporting infrastructure based upon a common suite of interoperable software, open standards, data formats, and data models that allows geospatial data and information to be efficiently collected, generated, managed, analyzed, used, visualized, and disseminated, from peer to peer, echelon to echelon, Army to Joint, Army to Coalition and Army to Intelligence Community. The AGE is a key supporting component of the LandWarNet/Battle Command Strategy." (TRADOC Capability Manager Geospatial 2009)

Two key points emerge from the Organizing Principle. First, the definition of value is based on the service of increasing the understanding and situational awareness of decisions makers within the spectrum of Army Operations. This is different than if the AGE were producing map products as the definition of value. The enterprise boundary continues out to the cogitative domain of the maneuver elements. Second, the AGE cuts across all aspects of the Army Enterprise, "organizations, technologies, policies, doctrine, and materiel solutions" within the area of the geospatial information. Therefore, the transformation of the AGE should take a holistic approach to all "levers" of change within the enterprise.

2.5.1 Strategic Environment of the AGE

The Army Geospatial Enterprise seeks to address the needs of battle command. The "enterprise identity" is relatively new and grew from experimentation, analysis and programmatic efforts primarily at the Army Geospatial Center and the TRADOC Capability Manager for Geospatial. The architectural effort occurs within a movement within the Army, and more generally the Federal government, to attempt to gain efficiencies through architectural efforts focused on enterprise with information technology components. The next sections broadly describe Enterprise Architecting efforts within the DoD and how these efforts are nested within the Federal Government's efforts as well as how the DoD EA philosophy organizes the subordinate military enterprises. The motivation of the discussion is to place "where" the Army's Geospatial Enterprise resides in the larger context of DoD Enterprise Architecture in order to provide insight into how proper AGE decision making increases value creation within the DoD.

2.5.1.1 Brief History of Federal Government Enterprise Architectural Efforts

The use of Enterprise Architecture techniques within the Federal Government began with the need to reduce the costs of information technology across all federal agencies, based upon the vast amount of government spending in the area of information technology, including hardware, software, and service contracts. Given that the "burning platform" for EA usage originated in IT costs, it is understandable why EA solutions tend to focus narrowly within the IT perspective. But this narrow focus flagrantly misses the potential value of a holistic perspective on Enterprise Architecting and subsequent transformation efforts.

The Federal Government, through Congressional legislation and Executive action, determined that Enterprise Architecture has the potential to make the government more resource efficient and functionally effective. The Clinger Cohen Act of 1996 initiated the requirement for Federal Departments to use Enterprise Architecture. The motivation for the legislation was to save money on IT while making government business operations more productive. This would be achieved through better resource sharing and smarter IT purchase decisions due to better understanding of the federal enterprise. Much of the power of EA was obscured from the beginning due to the continual focus on IT system acquisition. Section 5123 of the act, Performance and Results-based Management, is buried deep in the bill, and perhaps the most powerful capability of EA is listed toward the bottom of the purposes of the legislation. "5) analyze the missions of the executive agency and, based on the analysis, revise the executive agency's mission-related processes and administrative processes as appropriate before making significant investments in information technology that is to be used in support of the performance of those missions;" (Clinger Cohen Act 1996) In this case the inclusion of the Information Technology Acquisition decision is approximately at the end of the EA effort, which has focused on other views first.

2.5.1.2 The Federal Government Architecture

Broadly, the Federal Enterprise Architecture Framework (FEAF) is "a business-based framework for cross-agency, government-wide improvement" (Bellman and Rausch 2004). The framework consists of a collection of five different reference models that act as categories of models allowing OMB to compare the efforts of all of the departments using the same terminology and metrics. The reference models are the Business Reference Model (BRM), the Performance Reference Model (PRM) the Data and Information Reference Model (DRM), the Service Component Reference Model (SRM) and the Technical Reference Model (TRM.) The goal of common EA (albeit IT centric EA) vocabulary is beneficial, and the ability to program funding and provide IT eGov cost savings is helpful, but given the broader EA possibilities outlined in the CCA above, this seems quite underachieving.

In summary, the FEAF seems like a good idea given that the departments realize that "E-Government entails enterprise and cross-agency perspectives, and in doing so take a long view or holistic perspective." (Bellman and Rausch 2004) A holistic perspective aimed to reduce redundancy and duplication can improve the efficiency of the Federal Government significantly. The DoD attempts to nest the Federated Department of Defense Architecture within the broader Federal Enterprise Architecture.

2.5.1.3 Department of Defense Architecture

In order to enable the development of architectures within the Department of Defense, the Department of Defense Architecture Framework evolved. The most recent version of the DODAF is 2.0

which was published in 2007. This is the second generation of the framework following its migration from the C4ISR Architecture Framework. The

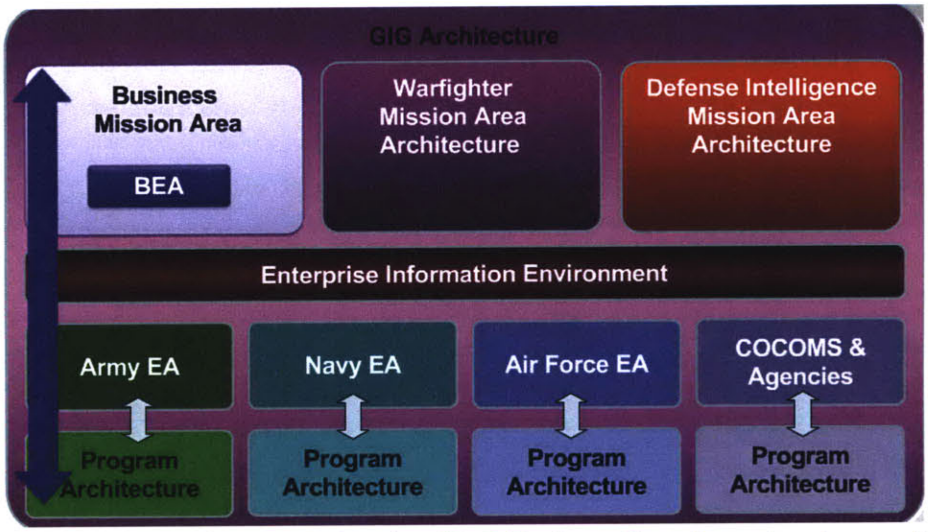


Figure 2-7: DoD Architecture Federation (DoD Business Transformation Agency 2008)

In summary, the DoDAF is an evolving framework that seeks to organize and manage information about an architecture which in turn can increase the value delivery of complex enterprises operating as socio-technical systems (DiMario, Cloutier and Verma 2008).

2.5.1.4 The Army Enterprise Architecture

The Army Enterprise Architecture is an overarching structure and vocabulary to enable putting the components of the Army into a larger consistent context. The AEA takes all of the functions of the Army and places them within a shared context in order to align strategy processes and other enterprise characteristics.

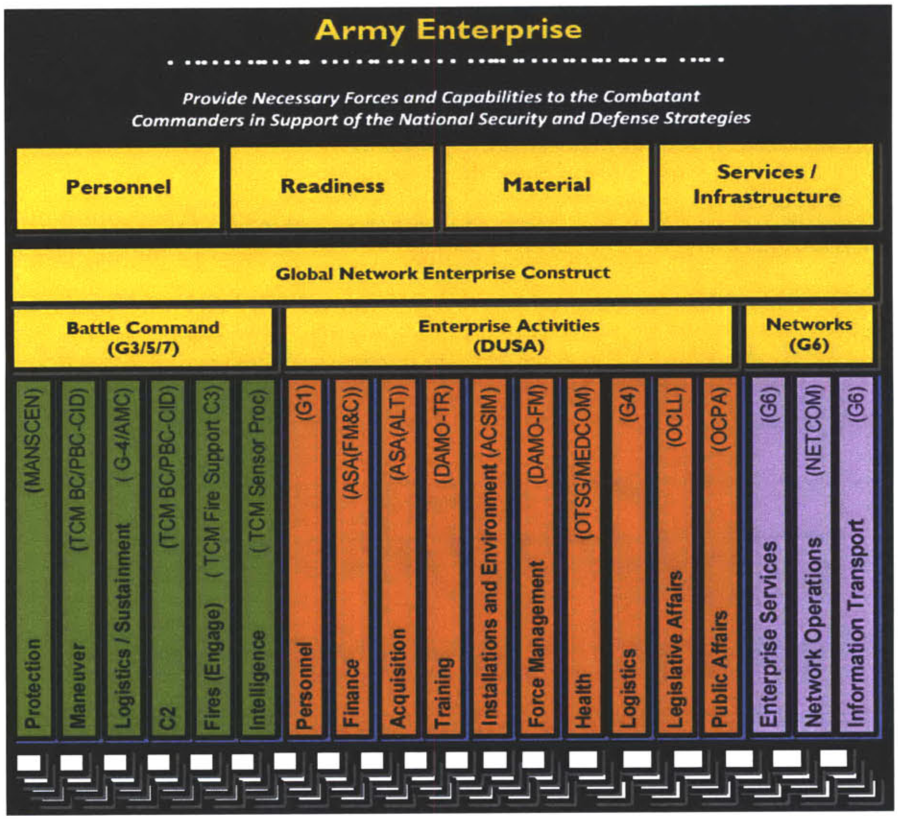


Figure 2-8: Army Enterprise Architecture (Bechtold 2009)

The AEA components are divided up into enterprises, segments and solutions, each nested within a higher layer. Within this framework the Army Geospatial Enterprise acts as a segment within the larger enterprise with many "solutions" as AGE subcomponents. Figure 2-9 depicts the nesting of the segments and solutions within the Enterprise Architecture level. The modeling detail and impact perspective change with each level as well.

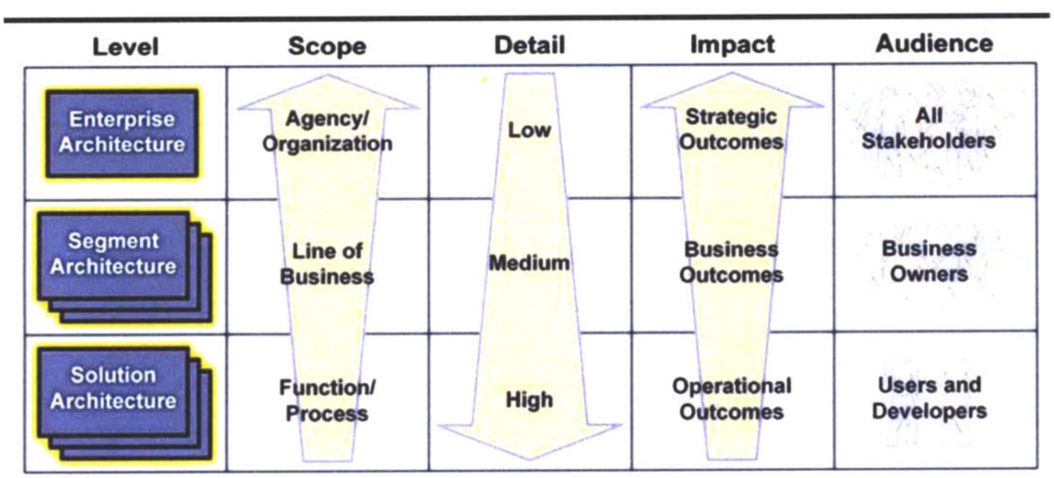


Figure 2-9: Army Enterprise Levels and Value Chain (Army Architecture Integration Center 2010)

2.5.1.5 The Unified Battle Command Architecture

The AGE is also nested within the context of a larger set of enterprises. The AGE supports the Unified Battle Command enterprise which sits within the Army Enterprise Architecture. Unified Battle Command has segment architectures for each of the Warfighting Functions and in turn these segment architectures have solutions, or material programs, training, and doctrine that support each of them. The AGE sits primarily within the Battle Command architecture, supporting the ability of battle command to place entities accurately in time and space. The AGE provides information of the "geometry" of the battlefield in order to enable tactical decision making within battle command. Figure 2-10 depicts the Unified Battle Command Architecture with the addition of the AGE inside of the Battle Command Enterprise enabling the interaction with the other WFFs.

Figure 2-10: Capability Set – Portfolio Framework, Global Network Enterprise Construct (adapted from Department of the Army Chief Information Officer/G-6 2009)

2.5.2 Enterprise Objectives

The objective of the AGE is to support effective battle command through geospatial information and services. In order to achieve this goal, synchronization of geospatial information throughout the enterprise is necessary. The AGE seeks to achieve this through standards formulation and enforcement across the Army Acquisition community and for data producers and consumers across the Army.

> "The long-term objective is to administer and facilitate the development of a net-enabled Army geospatial enterprise with a distributed database coupled with an enabling information architecture based on enforceable policies and procedures, interoperable software, open standards, open data formats, and approved algorithms. Such a geospatial enterprise allows actionable geospatial information to be tasked, posted, processed and used as needed vertically and horizontally; from peer to peer, and bidirectionally from National to Soldier level." Geospatial Governance Board Charter (Visone 2009)

2.5.3 Enterprise Processes

The following generic value stream map of geospatial operations provides some insight into the enterprise processes within the Army Geospatial Enterprise.

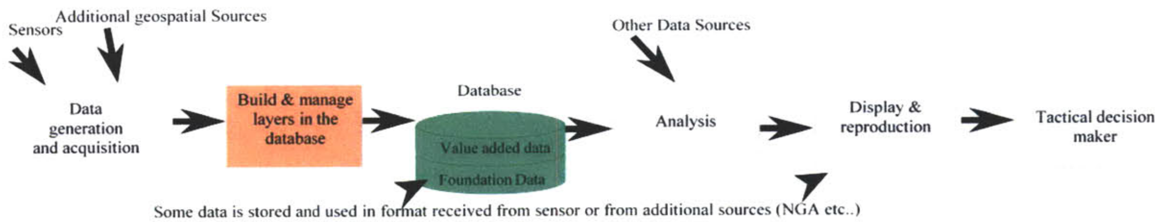


Figure 2-11: Generic Geospatial Value Stream Map (adapted from Wright, 2002)

The analysis in this thesis will focus primarily on the Foundation Data layer of the value stream of Figure 2-11: Generic Geospatial Value Stream Map (adapted from Wright, 2002). Foundation data is defined by the AGE Concept of Operations (CONOPS). "The GF layer for the COP results from storing, managing, and collecting all operationally relevant spatial and temporal data in a standardized, distributed geospatial databases which then enables sharing, correlation, and fusing of data across the Army, from all six warfighting functions (WWF), movement and maneuver, fires, intelligence, sustainment, command and control, and protection. GF data is collected from NGA, JIIM partners and commercial sources. The GF data will be replicated from Army GPCs to the Corps, Division, and BCTs to support the building of the COP. WFF geo-enabled applications will build data layers upon the GF. Initially, the GF is comprised of baseline geospatial data from the NGA, Army Geospatial Center (AGC), Army Geospatial Planning Cells (GPC), along with other mission area data." (TRADOC Capability Manager Geospatial 2009)

2.5.3.1 Tracking an Example of an Enterprise Process through the Value Stream

In order to best understand the generic value stream discussed above, it is best to show the complexity of the stream by way of specific example. Often times the value stream does not reside completely within the Army Geospatial Enterprise. The value stream may originate within the National Reconnaissance Office (NRO), the National Geospatial-Intelligence Agency (NGA) or within a detached commercial imagery vendor. These sources may then feed into the Army Geospatial Enterprise at different locations along the AGE value stream, while other programs and data sources may have their entire value stream contained within the AGE.

The value stream, though shown here linearly, is very cyclical in nature. Almost all portions of the value stream are active at all times. There may be feedback from downstream lessons learned that will impact revising upstream processes. For example, a determination made during the display and process at the Operations Order Briefing, may require that the terrain team acquire, analyze and distribute a new product or set of data. These adjustments to the value delivery are common in operations. The value stream is portrayed as linear to simplify the representation.

In order to best show the entire AGE value stream, an insular example will be discussed first.

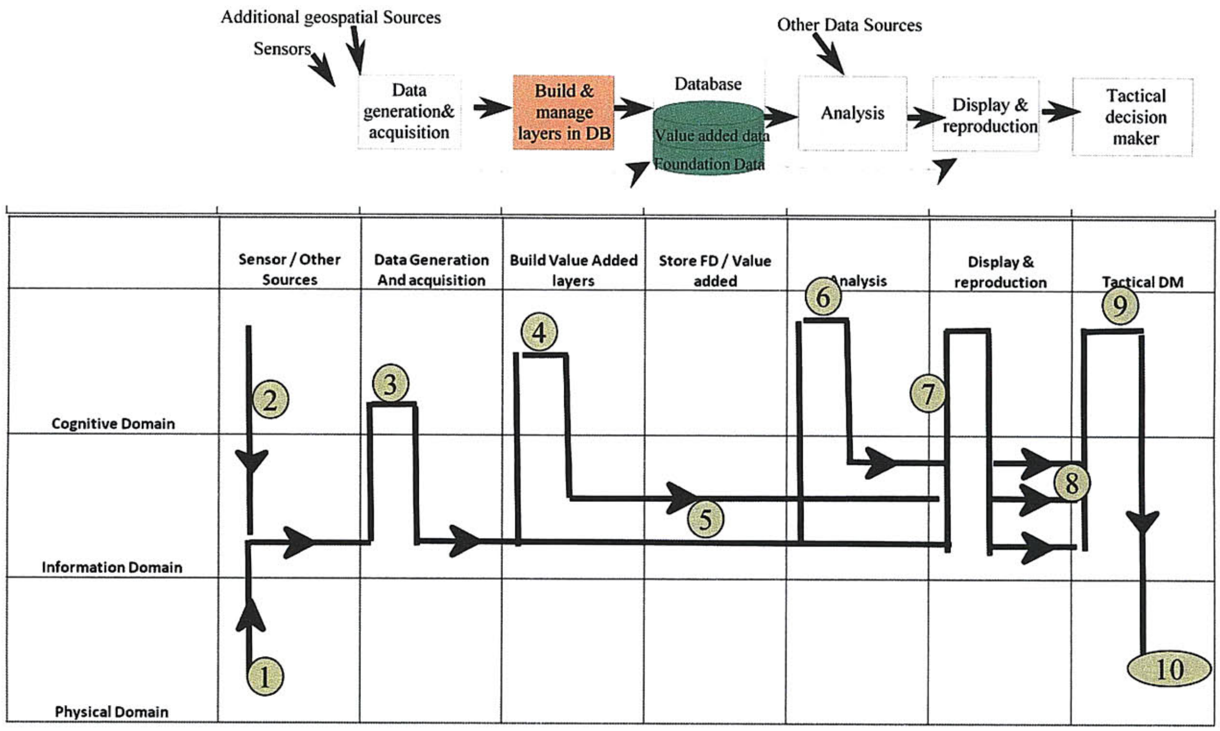


Figure 2-12: Geospatial Value Stream Mapped Across Warfare Domains

Each step of the value stream is now defined with a representative example to illustrate the way in which the Army Geospatial Enterprise delivers value. This discussion is not exhaustive of all the ways in which the AGE delivers value. As shown in the stakeholder analysis, there are many value exchanges across the enterprise, each of which has a value stream and value delivery process. The focus of this value stream is the delivery of geospatial foundation data, one portion of the enterprise's value proposition, down to the tactical decision maker at the brigade level.

1. <u>Sensing the Physical Domain</u>: the physical domain can be sensed directly by humans, or indirectly through a technical sensor system. The majority of geospatial foundation data is sensed indirectly through some type of sensing system, usually at a national level, purchased commercially, or some tactical ground or airborne sensor system. The raw data is typically in a proprietary format based on the sensor type and manufacturer. Examples are range files from a LIDAR or pixel values from digital imaging system.

2. <u>Obtaining Information from Outside Sources</u>: typically outside sources are obtained from a similar value stream at a higher echelon. This is used to build the Geospatial Foundation Layer before deployment.

   There are several ways that the geospatial foundation data can be initialized.

   a) A hierarchical push from their next higher echelon, typically on an external hard drive
   b) Ordering the products (digitally or in paper copy) from the Defense Logistics Agency (DLA), typically serviced by the Richmond Map Facility

c) Retrieve the products from NGA Gateway
d) Receiving a push of data from the Central Technical Support Facility (CTSF) at Fort Hood, typically filling FBCB2 systems with standard map data
e) A combination of the above methods to populate a complete Geospatial Foundation

3. Evaluating the Data: the terrain team inspects the information as they bring it into the geospatial database. They determine the quality of the data and who else in the brigade would need this information. If there are discrepancies in the information the team will work to purge the database of conflicting references.

4. Building new data, extracting features: The terrain team is trained to generate geospatial information from multiple sources in order to meet the information needs of the brigade.

5. Database management: the physical storage and connectivity of the geospatial information servers to the TOC network is facilitated by the terrain team and the geospatial information system software and hardware provided by the geospatial portion of the Distributed Common Ground Station – Army (DCGS-A).

6. Analyzing Geospatial Foundation layer with other sources and in context: conducting terrain analysis and creating specialized terrain products is a key task for the brigade terrain team. They seek out a diverse set of data sources, from operation reports to intelligence information in order to understand all aspects of the terrain. Geospatial products are usually a synthesis of other information sources, which places the final terrain product at a higher level along the information domain producing information that is actionable.

7. Determining what information should be included and shared: as the mission planning process proceeds, there are many geospatial information requests from across the warfighting functions. For example, the reconnaissance element may request line of sight analysis to determine the best place to insert an observation post. Each request requires individual attention as to what information would best serve the mission. In this way, the information flow is a combination of data "push" based upon a core set of needs to provide the foundation of the common operating picture, as well as a "pull" from Requests for Information (RFIs).

8. Information exchange: The information exchange to the tactical decision makers occurs at several points along a mission time line. The Mission Analysis Briefing is usually the first opportunity for the commander and staff to receive a set of geospatial products from the terrain team, and for the terrain team to synchronize the COP that will be used for the operation. The Operations Order Briefing occurs at the end of the planning cycle and before mission execution. This is another opportunity for the geospatial foundation layer to enter the decision-making process of the planners and Soldier conducting operations.

9. Understanding and decision making across the battle command functions: commanders and leaders at every level in the brigade must constantly make tactical decisions based upon their understanding of terrain. They have built mental models of the terrain based on geospatial information as well as their experience from operating over the terrain. From these mental models they determine the military impact of the terrain upon operations, including the effects on friendly, enemy and civilian elements.

10. Taking Action: During the operation, the geospatial foundation layer will be referenced to aid in navigation, target location and other basic mission execution requirements.

2.5.3.2 Geospatial Information Domain

It is now possible to focus more intensely on the geospatial information domain specifically. If the entities of the above value stream map are projected together across the information domain, a hierarchy of geospatial information domain states emerges.

Table 2-2: Hierarchy of Geospatial Information Domain

Hierarchy of the Geospatial Information Domain

	Cognitive Domain	
Information Domain	terrain information in natural language	Tier 3
	tactical decision aid specialized to operation	
	annotated analytic products	
	analysis of battlefield effects of terrain	
	fusion of geospatial sources	
	additionally attributed extracted features	Tier 2
	extracted feature data	
	standard map data	
	orthorectified mosaics of imagery data	Tier 1
	orthorectified mosaics of elevation data	
	raw sensor data	
	Physical Domain	

Typically more effort is required to move information up the hierarchy, beginning with the raw sensor data at the lowest level. This is seen along the value stream map as raw sensor data enters the enterprise and is transformed into higher levels of information along the hierarchy by manipulation in the cognitive domain of people in the enterprise.

2.5.4 Enterprise Summary

The Army Geospatial Enterprise is a complex socio-technical system that spans from national level strategic systems and capabilities down to the cognitive models that inform the decision making of virtually every Soldier operating within the battlespace. Though the enterprise value stream, displayed in Figure 2-11 shows a linear value stream at only one level of the enterprise, this approach is used for the sake of simplicity. In reality, the value stream of the enterprise combines this generic value stream map at the national level (the Army Geospatial Center for example) the theater level (a Geospatial Production Cell (GPC) attached to each COCOM) and at multiple tactical levels (division and brigade levels for example). Another complicating issue is that the value stream is not linear in practice. There is much iteration along the value stream, making GEOINT at the tactical level more a cycle, with continuous value deliver, rather a discrete stream (Feser 2010). A more correct, though unfortunately more complex version of the generic value stream is given in Figure 2-13.

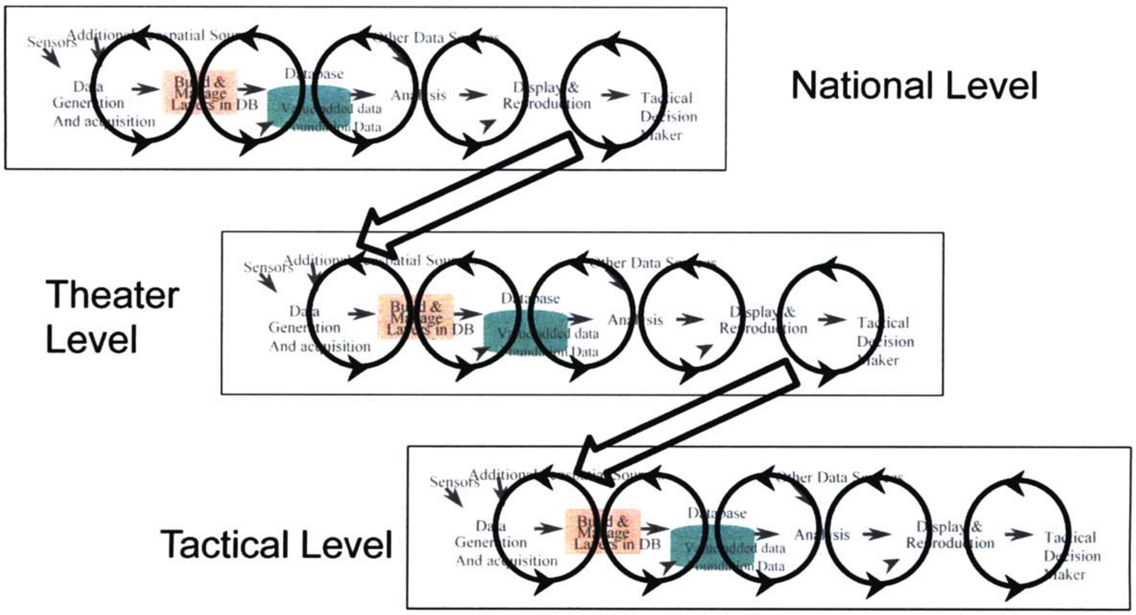


Figure 2-13: Value Stream as Nested Cycles

2.5.5 Geospatial Information and Utility Measurement

The Army Geospatial Enterprise generates information internally as well as requires external information in order to serve decision makers and planners. This information requirement must be considered holistically throughout the value stream.

> "Intelligence support, every bit as much as ammunition, fuel, spares, and training, is required to make today's military systems work. Too often in the past, a new weapons system was designed on the presumption that the information it needed to consume would appear, as if by magic. Often, the Intelligence Community was able to work that magic. In today's fiscal reality, there is little or no discretionary resource left for such tricks. Such requirements, which can be forecast easily, must engender early debate about their dependence on an intelligence tail. Ignoring the intelligence bill—people as well as systems—at the outset precludes sound planning, programming, and budgeting,

and forces invidious choices later on." (Independent Commission on the National Imagery and Mapping Agency 2000)

The Army Geospatial Enterprise enables the Geospatial Foundation (GF) information as well as the sharing and fusion of "layers" of information from all warfighting functions (WFFs) on "top" of the geospatial foundation. The focus of this thesis is upon the geospatial foundation data. This is a subset of geospatial information, which in turn is a subset of GEOINT.

The utility of the geospatial foundation data is based upon the quality of the geospatial information contained in the foundation. Another factor that plays into the utility of geospatial information is the degree to which the decision makers trust the information they are given.

Table 2-3: Relationship of Quality of Information and Trust in Model

		spectrum of user's belief in geo-data	
		Model trusted	Model not trusted
spectrum of quality of geospatial information available	Geospatial Quality level above required	excess quality may confuse user and decrease utility	extreme waste of resources, uninformed decisions
	Required quality level met	useful decision making tool	wasted resource, uninformed decisions
	Low Quality of geospatial information	bad tactical decisions based on incorrect terrain understanding	not trusted for good reason

The trust that leaders have in the geospatial information directly impacts that utility that information will have on operations.

2.5.6 Uncertainty of the Enterprise Environment: Changing Resources and Geospatial Needs

The uncertainty of the environment in which the Army Geospatial Enterprise will operate in the future is presented here in order to prepare for the discussion of value robustness of the enterprise during the future state discussion in chapter four. The military operating environment is constantly changing in many dimensions, and these changes must be considered during enterprise design. The enterprise does not have direct control over these factors. Although they are not inside the enterprise boundaries, the enterprise must react to all pertinent environmental factors to be successful. There are also ways in which the enterprise may be able to influence some of these factors, by lobbying for specific policy or regulation changes or through investment in ancillary commercial technologies.

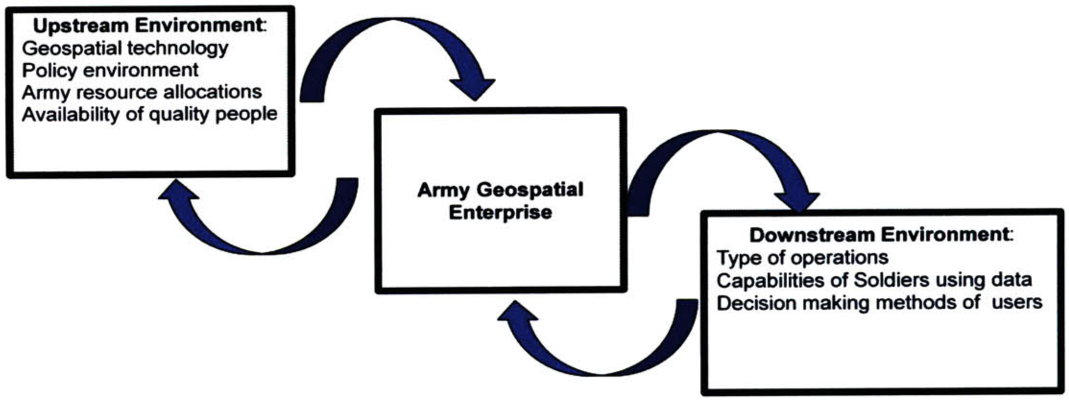


Figure 2-14: Uncertainty Driving Need for Enterprise "ilities"

2.5.6.1 Uncertainty of Upstream Environment

The upstream environment of the AGE consists of all of the factors that form and shape the front end of the AGE value stream. They include the geospatial, communication, and battle command technology that the AGE can utilize and leverage in its architecture. The Intelligence Community and other National level agencies also contribute to the baseline data environment that the AGE inherits as a starting point for the foundation data. The policy decisions of the DoD and Army leadership also impacts the programmatic capabilities of systems and products within the AGE. For example, the terrain analysis information systems that deploy with the terrain teams are impacted by Army and DoD level budgeting decisions outside of the control of the AGE. Finally, the talent pool that the AGE pulls from to train and deploy as analysts changes over time as well.

There are many possible political climates possible in the US, and it is difficult to stereotype political environments and gauge possible effects of the political environment on the DoD such as policy direction and budget allocation. Typically, the Presidential political tone will impact the DoD Operational Tempo (OPTEMPO) and funding levels more directly, by way of the Quadrennial Defense Review (QDR) and other strategy documents, while the Congressional impact addresses budgetary constraints and policy adjustments written into legislation such as the annual defense authorization act. Though not always an indicator, a conservative perspective is usually more willing to spend money on defense, while neglecting domestic social issues and a liberal perspective is less likely to go to pursue international military intervention.

The US economic condition can also impact the ability of the AGE to deliver value. The economic condition impacts the ability of the country to fund military operations, acquisitions, research and development. As military operations become a greater portion of GDP, there will be reduction of available economic output for civilian standard of living, infrastructure investment, and other social programs. Also, the economic condition impacts the ability of the US industrial complex to support DoD business operations. As the overall economy deteriorates, the technical capability of the industrial base diminishes and the country's ability to innovate new military solutions decreases.

Finally, the world political and economic environment impacts the requirements levied against the AGE. When a stable hegemonic power governs international conduct, there is typically less requirement for military enforcement of norms; there must just be enough military development to maintain the hegemonic position. If a bipolar international environment exists, typically the two powers will be in competition with one another. This may create arms races and requirements for increased capability commensurate with the increases in the adversary's strength.

These environmental conditions change with time and impact the ability of the AGE to deliver value, and contribute to the success of the tactical decision makers. The AGE leadership is typically better poised to impact the upstream environmental condition than the downstream conditions. Technology investment and participation reduces the uncertainty around the future technological environment. Strong ties to the Army resource allocation process and favorably impact the AGE budget prioritization. Finally, partner organizations, such as the NGA, USGS, IC, and others, invite participation from the Army and other Services to help voice the desired direction and production priorities for their organizations. This type of participation helps anticipate changes in these organizations well before impacting the enterprise. Understanding the upstream uncertainty is critical for success, there should never be any "game changing" surprises in this area if close attention is paid to the stakeholder partners upstream of the enterprise.

2.5.6.2 Uncertainty of Downstream Environments

Similar to the upstream environmental drivers, there are downstream conditions that impact the ability of the AGE to properly deliver value as well. The nature and location (type of terrain) of operations impact the needs of the tactical decision maker. The spectrum of conflict determines the mix of operations that the Army will need to conduct during operations.

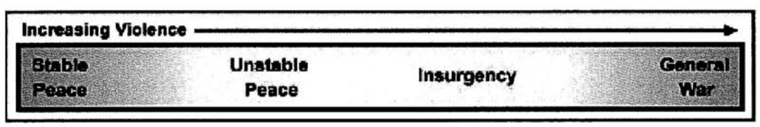


Figure 2-15: Spectrum of Conflict (Field Manual 3-0: Operations 2008)

The placement on the spectrum of operations defines how the elements of full spectrum operations combine. The spectrum of conflict is defined by FM 3-0 Operations in Figure 2-15, as stable peace through general war. The type of conflict will determine the Business Mission Area needs of the warfighter. The type of warfighter requirement changes depending on the spectrum of conflict. The types of geospatial needs for natural disaster response are different from those required for asymmetric counter insurgency operations. Each operation will contain some amount of the Full Spectrum of Operations, but the relative weight of each element will change as shown in Figure 2-16. There is significant uncertainty surrounding the likelihood of the type of future conflicts. Some of the criticism of the military surrounding the preparedness for Operation Iraqi Freedom is the apparent discounting of the Vietnam type of conflict in favor of the more traditional 1991 Gulf War conflict type. These assumptions impact warfighter doctrine and training, but also have significant impacts upon the type of geospatial information, systems, and training the enterprise pursue.

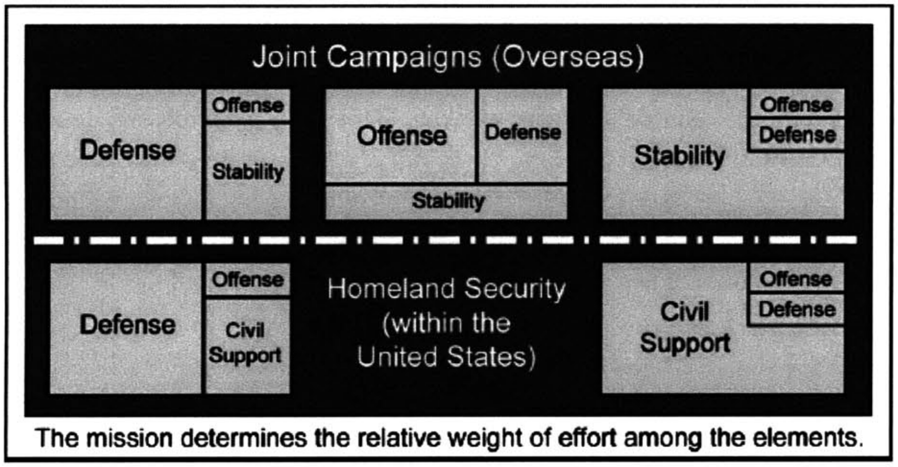


Figure 2-16: Full Spectrum Operations
(Field Manual 5-0: Army Planning and Orders Production January 2005)

2.6 Background Summary

Each of the environmental changes discussed above has implications for the AGE. Enterprise performance throughout the variation in contexts depends upon the architecture of the enterprise. The "-ilities" of the architecture help to describe how the enterprise produces value for the stakeholders in a changing world. The changeability of the current state and each of the future state candidate architectures described in chapter four will be compared using some of the possible future environmental conditions using Epoch-Era analysis.

The Army Geospatial Enterprise, though not formally articulated until recently, has a long history within the United States Army. Recent advances in technology and network centric warfare thinking require the AGE to perform in deeper and more interdependent ways. There are several efforts within the Army aimed to increase the capability of geospatial operations, both the information content and enabling systems.

3 Army Geospatial Enterprise Current Architecture

This research attempts to analyze the current Army Geospatial Architecture, determine a future state objective for the architecture that will deliver greater value, and describe some of the heuristics that can be applied to enable realization of the future state. This chapter deals with understanding the current state of the architecture, but in order to fully understand how the current state is delivering value today, one must first understand the stakeholders and current value proposition.

3.1 Current State Architecture Approach

The process of defining the enterprise landscape and the scope of the EA is vital to the success of the effort. The architect must identify the strategic motivation for an enterprise architecture effort. The business model, current level of performance, and desired future vision should inform the scope and direction of the EA. The EA team should have access to the enterprise leadership and the support of an EA champion who can keep the effort moving if obstacles are encountered. The enterprise landscape includes a stakeholder analysis with stakeholder values and desired future enterprise performance identified. Current state architecture also includes stakeholder prioritization which will help to inform the weights for value measurement in analysis in the following phases. Finally the EA approach determines the important or appropriate views for analysis. Once identified, the architect models the views, view interactions, and validates the current state understanding.

3.1.1 Value Creation Framework, Needs to Goals Analysis and Enterprise Views

The goal of the AGE is to create value across the enterprise. In order to understand how value is created and the actions necessary to improve value creation, it is helpful to apply a framework. Murman, et.al. (2002) provides a simple framework that helps to identify enterprise value-creation, according to his work there are three pieces to value-creation: value identification, value proposition, and value delivery. Each of these areas shed light into understanding the current state of the enterprise. (Murman, et al. 2002)

Table 3-1: Value Creation Framework and Detailed Approach

Objective	Value-Creation Framework	Framework to Articulate Detail
Find stakeholder value	Value Identification	Needs to goals framework Steps 1-2
Agree to and develop the approach	Value Proposition	Needs to goals framework Steps 3-5
Deliver on the promise	Value Delivery	Eight Views of Enterprise Architecture

In order to dig deeper into each of the three areas of the value-creation framework, the Needs to Goals framework and the Eight Views of Enterprise Architecture will be applied as outlined in Table 3-1.

Each of the pieces of both of these frameworks, as applied to the AGE, will help to inform the value creation of the enterprise. The goal of the current state analysis is to enable effective transformation to the desired future state architecture.

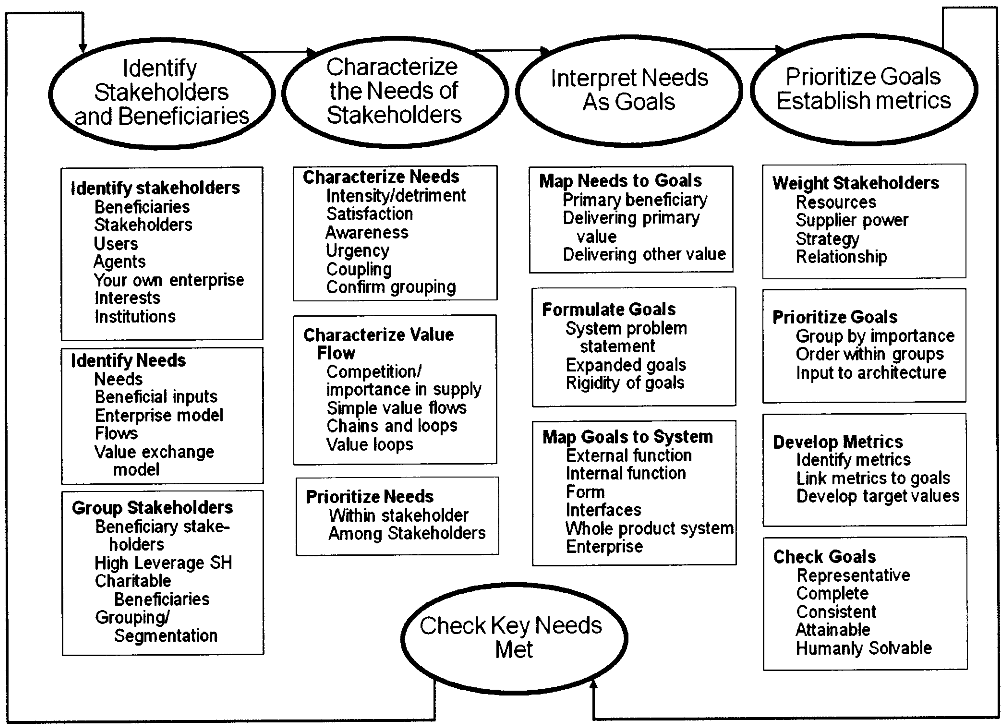


Figure 3-1: Crawley's Needs to Goals Framework (Crawley 2009)

The first two steps are to identify stakeholders and beneficiaries (step one) and to characterize the needs of the stakeholders (step two). In the broader architectural picture this occurs after the context has been defined and before the intent definition. These two steps are part of the value identification process and will be discussed in section 3.2.1. The final three steps in Crawley's (2009) needs to goals framework include interpreting the needs as goals, prioritizing goals while establishing metrics and checking whether needs are met. These final three steps in the framework are part of the value proposition, and are discussed in section 3.3.

The discussion of enterprise value delivery is conducted using the eight enterprise views, a framework developed by Professors Rhodes and Nightingale in the MIT Engineering Systems Division.

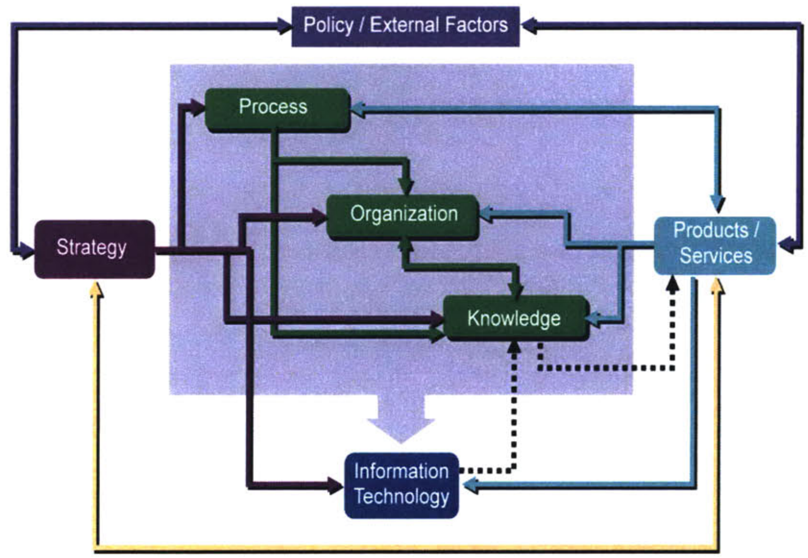


Figure 3-2: Holistic Enterprise Architecture Framework (Rhodes, Ross and Nightingale 2009)

The views shown in Figure 3-2: Holistic Enterprise Architecture Framework Figure 3-2 represents aspects of the enterprise which interact to create value. Each of the views has structure, behavior, a set of associated artifacts, measure, and some periodicity to the view. The structure of each view refers to the objects and connections of the elements of the view. The behavior is what the structure does over some time period. The artifacts of the view are tangible items that the enterprise uses to help define, organize, or control the view. The measures are defined by the enterprises in order to observe the performance of the view. Finally the periodicity of the view defines the timeline lifecycle over which the view evolves. Each of these descriptions of the view helps to define the current state of the enterprise architecture.

3.1.2 Survey and Interview Process

The data needed to analyze the current state of the enterprise was collected through surveys and interviews. A formal survey sought to understand the benefit that the AGE provides to the lowest echelons of the Army, down to the dismounted Soldier. The survey was sent to over 300 current and past geospatial engineers, terrain analysts and geospatial leaders up to the rank of major. There were 25 responses to the survey spanning the rank of private to major from a wide variety of positions and mission areas. All respondents are intimately involved in the creation, storage and distribution of geospatial information across the Army. The survey focused on the interactions of the Geospatial Engineering Team, also known as the brigade terrain team, in order to understand the needs and interactions down to the lowest levels of tactical decision makers. The brigade is the lowest echelon of the Army that has a terrain team. This team serves the brigade commander, staff, and all subordinate units. A survey of these brigade terrain teams (GETs) captures the widest understanding of geospatial requirements for tactical decisions. The survey contains five sections totaling 46 structured response questions that limit response to a drop down menu of options, with an additional opportunity for free text response in six other locations. The sections of the survey roughly followed the value stream of geospatial data within the terrain team. The first section was administrative data, followed by data acquisition and generation, data management and storage, display and reproduction, and finally geospatial understanding and military decision making. The results of the survey, discussed in 3.4 as well as Appendix B, help to define the current state of the enterprise, as well as inform the effects of changes in the design of the enterprise into the future state.

The author conducted an informal interview process of many personnel within the Army Geospatial Enterprise. Some of these were conducted face to face at the Army Geospatial Center, Fort Belvoir Virginia, during a series of two multiday discussions, one in December 2009 and the second in March 2010. Other interviews consisted of phone and email correspondences with Army Geospatial Leaders from TRADOC Capability Manager- Geospatial, Fort Leonard Wood, and MO; as well as throughout the Army force structure.

From both of these efforts, the two primary areas of the enterprise addressed are the leadership of the Army Geospatial Community and the terrain team from the brigade level. This is only a subset of the entire AGE, but the interview process also attempted to reveal the needs and preferences of adjacent individuals within the geospatial value stream. This includes the individuals who directly interact with the Army leadership (Battle Command for example) and the tactical decision makers down at the brigade level and below.

3.1.3 Modeling of the Enterprise and Boundary

In the current state of the enterprise, the boundary of the enterprise exists at the brigade level, as geospatial information leaves the AGE and enters the cognitive domain of the tactical decision maker at the deliberate planning cycle or during mission execution.

The decision process employs both geospatial information and all other warfighting functions in order to make a tactical decision. The decision makers on the battlefield are the primary beneficiaries of the geospatial enterprise (discussed in the next section) so that understanding how benefit is transferred across this boundary is critical to value delivery. A model is built in order to best understand the interaction of information at this low level of the enterprise and simulations based on this model will help to inform the relationship between design variables and desired attributes. The goal is to gain understanding about the higher level enterprise decisions, and how these design changes impact value deliver across all stakeholders of the enterprise. The model will be discussed in section 3.6.

3.2 Value Identification

The value identification for the enterprise begins with a detailed stakeholder analysis. The benefit, worth or utility of the functioning of the enterprise must be defined by considering the total effect upon all of the stakeholders. A sustainable enterprise typically has relatively balanced value changes among the stakeholders. In a commercial enterprise many of the value exchanges are bilateral, with a direct value exchange, similar to an arms-length transaction within a market environment. But within many government enterprises, value is oftentimes not directly exchanged. There may be a chain of several stakeholders that must all pass on value before the benefit returns back to the originating entity. This extra degree of complexity has the potential to create dysfunctional value exchanges or to over or under realize production, activity or value in part of the enterprise, creating waste in the system.

3.2.1 Stakeholders and Beneficiaries

The first step of the value identification process is to identify stakeholders.

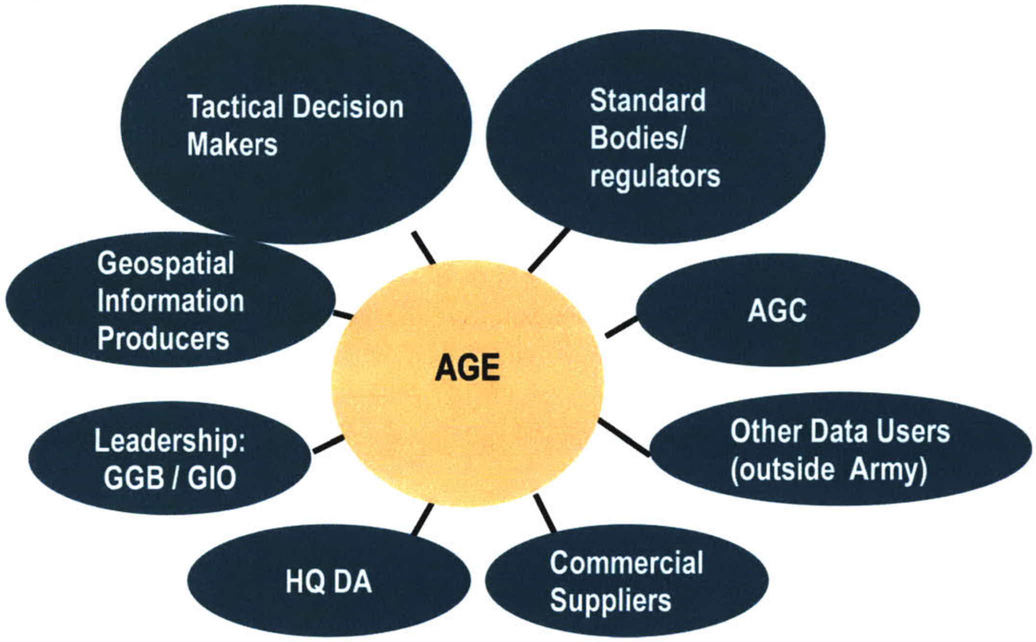


Figure 3-3: Enterprise Stakeholders

3.2.1.1 Direct Beneficiary:

The principal beneficiary of the Army Geospatial Enterprise is the tactical decision maker. The tactical decision maker is the Soldier that uses the provided knowledge (by means of information (data + meaning) (Devlin 2001) of terrain to properly inform this mental model to enact the best possible tactical, operational, or strategic decision. The need that is being filled is a lack of understand of terrain, most significantly, poor understanding of complex terrain. This stakeholder segment has two sub-categories. First, the mission planner uses geospatial information in order to understand the environment within which they are conducting the Military Decision Making Process (MDMP or Planning "Design"). The second sub-category is an operator conducting the operations (decisions such as navigation) typically these are made in a naturalistic way using a Recognition-Primed Decision Model (Klein 1999).

3.2.1.2 The Primary Benefit:

The primary benefit of the system is to effectively inform the decision-making of combat leaders. Tactical decisions predicated on poor knowledge of the terrain have a lower probability of mission success.

3.2.1.3 Non-primary Benefits:

The direct beneficiary can glean non-primary benefits as well. For example, the geospatial data collected for Forward Operating Bases (FOBs) can be used for "real property" accountability. Military

Business Mission Area needs can be fulfilled even though the primary benefit is for Warfighting Mission Area purposes. For example, base infrastructure can be inventoried and evaluated using the geospatial data available. This benefits the direct beneficiary in addition to the primary benefit

3.2.1.4 Indirect Beneficiaries:

There are several indirect beneficiaries, such as the host nation civil authorities who may benefit by having access to improved geospatial information. They have been able to use the data in several ways. For example, civil engineers in Kirkuk (a city in Iraq) were able to conduct a survey of a gravity fed sewer system that they were designing and building using the LIDAR elevation data. The high resolution data sets of geospatial data in the urban areas of Iraq and Afghanistan have helped other local users similarly.

3.2.1.5 How Benefit Flows to Indirect Beneficiaries:

In order for the benefit to flow to indirect beneficiaries, there must be a military release of the data for civilian use. This typically occurs through a foreign disclosure officer (FDO) who must make an assessment that the information would not harm the security of the forces and would benefit the military mission in some way.

Table 3-2: Stakeholder Segmentation and Needs

Segment	Example Stakeholders	Needs
Tactical Decision Maker	Commanders	easily understand the impact of terrain on decision making
	Staff planners	understanding of terrain, ability to bring all information together on COP
	operators, mission executers	Situational awareness, model of terrain for navigation / target description
Geospatial Information Producers	Product Originator / team	Funding, notoriety,
	Army Geospatial Center (enterprise)	funding, superior geospatial products
	communications (DISA...)	satisfaction with communication infrastructure
	logistics (DLA...)	satisfaction with physical product supply (hard media, paper copies)
Suppliers	Technology Development	revenue from hardware/software; knowledge of / stability of requirements
	Sensor system providers	revenue from hardware/software; knowledge of / stability of requirements
	Military Industrial Complex (NG, SAIC, etc.)	revenue from hardware/software; knowledge of / stability of requirements
	Mapping Companies	revenue from data collection / processing service
	Army Aviation	use of aviation assets, safety in flight
	Third Party Contracted Aircraft	Revenue from delivery of flight hours
Other Data Users	Commonwealth Partners	"models" / maps of complex terrain and threat
	Coalition Militaries (i.e. NATO)	"models" / maps of complex terrain and threat
	Host nation military partners	"models" / maps of complex terrain and threat
	Host Nation Civil Applications	geospatial data for planning, assessment of disaster, land use, etc..
	Corps of Engineers / PRTs	urban civil structure assessment data
Regulators and Standards Bodies	OGC	use of their standards which generates participation and revenue
	NSG working groups (meta data, etc.)	funding to continue operations; adherence to WG standards
	CHIPPM	safety of soldiers during operations
	AWR boards	safety of Soldiers and aircraft during operation
HQ DA	Enterprise Leadership: GGB / GIO	
	ASSALT	cost effective and beneficial material solutions
	PEO C3T	the success of all subordinate programs
	PM Battle Command	interoperability, usefulness by BDEs, low lifecycle cost solutions
	PM DCGS-A	interoperability, usefulness by GETs, low lifecycle cost solutions
	HQ Army G/3/5/7	tactically relevant geospatial support
	HQ Army G8	cost effective military (programs within budget)
Geospatial Engineering Teams(GET)	Terrain Team as data manager	geospatial data to provide COP
	terrain analyst	geospatial data to develop value added products

The chart above details the stakeholders, both problem stakeholders and beneficial stakeholders. There are no charitable beneficiaries, since the data is not publicly available, so there must be some linkage between the use and benefit to the US Government. Through one or multiple transactions, the benefit from fulfilling these needs will cycle through the system and back to the originator of value. This value transfer can be a tangible asset, like money based on contractual agreement, or a political "win" for the generator or owner of the source, which potential would increase that organization's future budget based on the value it is delivering back to society.

3.2.1.6 In order to simplify the above list of stakeholders, segmentation is beneficial. Groups of stakeholders who act with similar preferences and needs are combined into one segment. The following segments are chosen to enable the mapping of the flow of value amongst the stakeholders of the enterprise.

- Tactical decision-makers can range from a squad leader trying to decide which house the sniper is located in, to a division commander trying to decide the location of his 20,000 soldier Forward Operating Base.
- Suppliers consist of army "contractors" that provide the enterprise with hardware, software and services to enable all facets of the enterprise. This includes sensor system development to forward deployed geospatial analyst support, data generation,

processing and storage hardware and software, as well as a wide range of research and development efforts.

- Standards bodies and regulators are segmented together. They consist of agencies that conduct oversight over military procurement and operations. Some examples are the security regulators for foreign disclosure of sensitive information. Also, the "net worthiness" regulators that provide acquisition elements with the ability to operate new systems on the Army network.
- Segmentation of the Army headquarters elements (G3, G8 ASAALT and Officer of the Chief of Engineers) identifies commonality between each of these stakeholders. They desire the most effective military, with the fastest possible technology delivery, all done at lowest possible cost (which is politically achievable).
- Other data users make up the final segment and represent all of the other data users (host nation, researchers, etc…) these are non military decision makers / analysts that have some US Government connection. Their primary concern is the quality of geospatial data, and the data being unclassified.

3.2.2 Characterization of Stakeholder Needs

Below are the segmented beneficiaries with a more detailed needs analysis for the Primary beneficiary (tactical decision makers) and the enterprise (Army Geospatial Center), as well as other significant stakeholder segments.

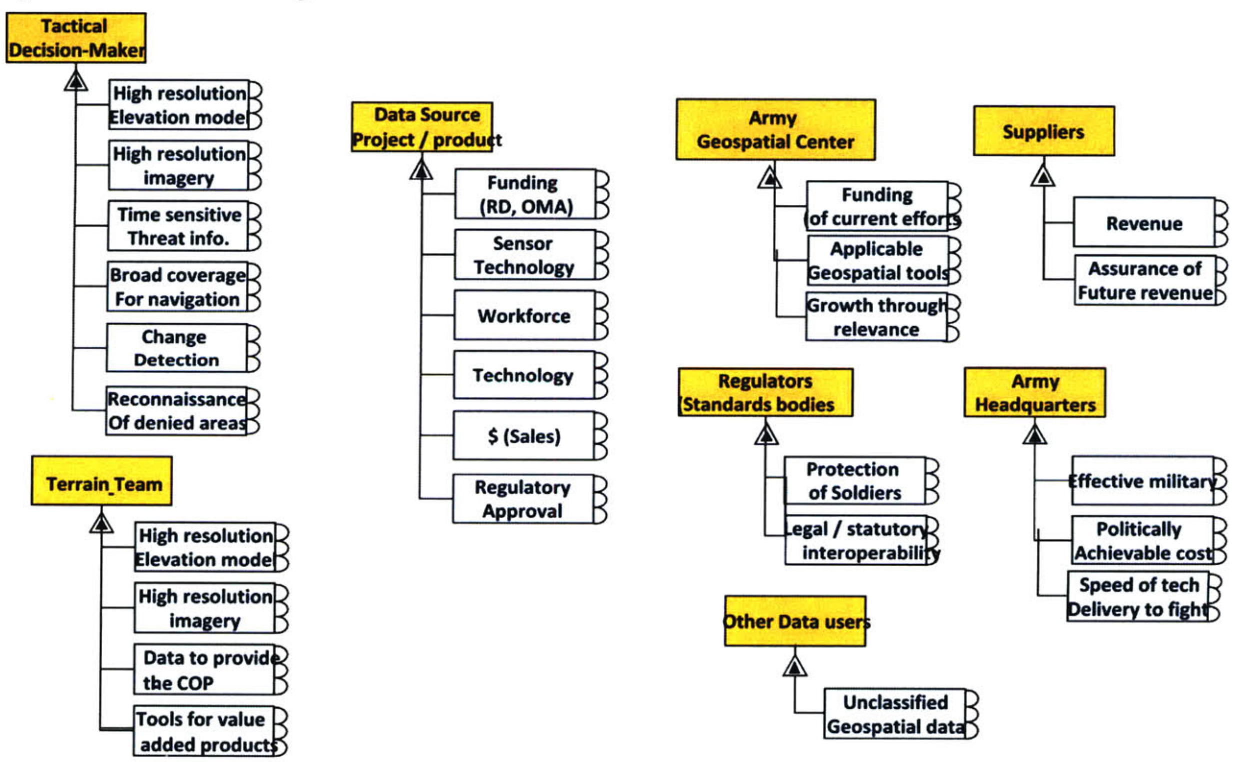


Figure 3-4: Segmented Beneficiaries and Decomposed Needs

One method deal with value exchange within complex enterprises is to create a value flow map. Some organizations choose to monetize the value exchange transactions within the organization in order to ensure fair exchanges. Another method is to charter organizations to force them to deliver value, even when not receiving value directly in return. The value flow map of the stakeholder segments of the Army Geospatial Enterprise demonstrates the complicated value interactions that must all function properly for value to smoothly flow among the stakeholders.

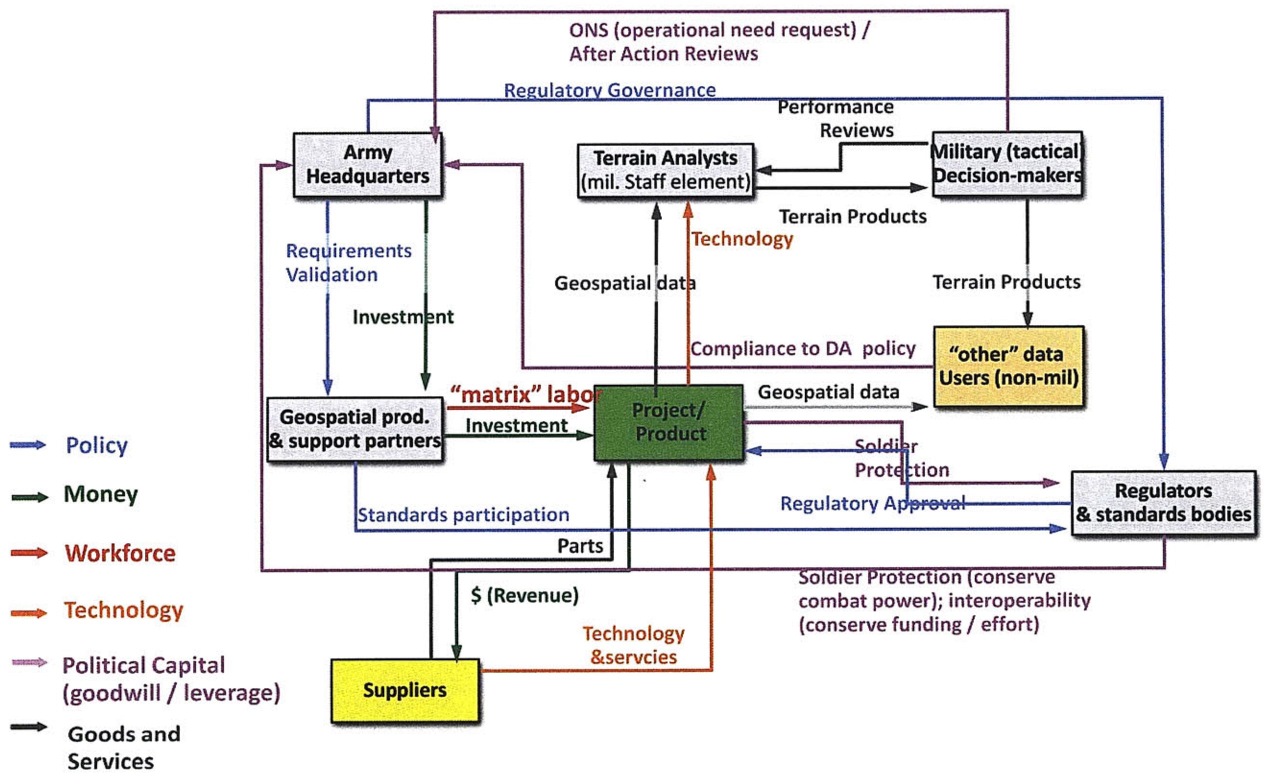


Figure 3-5 - Value Flow Map of System

The following insights emerge from the value flow map and prioritization of stakeholder needs. The list of prioritized needs will help to inform the enterprise problem statement in section 3.3.1.

- Prioritization of needs within a single stakeholder should be accomplished "intentionally" by the leadership of the stakeholder. One method would be to conduct an Analytical Hierarchy Process to determine when decision makers would be indifferent to two different "need levels." Then, derive a utility curve for variation in "need fulfillment." Then the current need fulfillment levels will apply to determining the most benefit (increase in utility per unit cost) for changes in the system.
- It is much more difficult to prioritize needs among differing stakeholders. There is no single rational decision maker to dictate priorities. The Analytical-Deliberative process (Apostolakis 2009) could be applied. This method uses the Analytical Hierarch Process

(AHP) to set preferences and then uses some type of physical model (economic NPV calculation for example) to set the stage for discussion by representative decision makers from the stakeholders. These individuals are brought together to discuss the outcome of comparison of their needs and how that might affect resource allocation (and therefore fulfillment of their needs.) This research does not explicitly address the problem of aggregating the utilities across the stakeholder segments, but rather focuses on the utility of the primary beneficiary as a proxy for the utility of the enterprise.

- The articulation of needs within the value flow map occurs at a higher level of the enterprise than where the needs are experienced. For example, the modeling of the needs of Intelligence, Surveillance and Reconnaissance (ISR) on the battlefield are conducted within the US Army Training and Doctrine Command, not by Soldiers that collect or use ISR on the battlefield. These studies yield requirements documents (owned by the TRADOC leads for individual capabilities) which flow to the acquisition community for engineering, development and procurement, stakeholders often well removed from the users.

3.3 Value Proposition

The enterprise value proposition defines the agreement between the stakeholders of the enterprise and the enterprise leadership. Sometimes this relationship is codified into a formal document such as a contract or charter. In other cases this relationship is built on tacit trust and historical adherence to norms and practices for beneficial gain. The communication of the value proposition must include an understanding by all parties as to the needs and goals of the enterprise, and how these needs will be met through the value deliver processes. Inclusion of prioritization within the value proposition will help to reduce future conflict among stakeholders by avoiding instances of unmet expectations.

3.3.1 Interpreting the Needs as Goals and Mapping on to the Enterprise

The enterprise problem statement defines that goals of the system based upon the needs of the stakeholders as analyzed above. The reason that the enterprise exists is to meet the needs of the primary beneficiary by filling the information needs of the tactical decision maker on the battlefield. If the needs of the primary beneficiary are not met, the enterprise is bound to fail.

It is helpful to condense the needs and goals of the stakeholders into a single purpose, or problem statement for the enterprise. One possible condensed form of the enterprise problem statement for the AGE is: *To increase the situational awareness and mental models of the terrain, By producing geospatial information Using the Army Geospatial Enterprise.*

The more complete version includes modifiers to the basic structure listed above, which captures the values of the stakeholders. The structure of the statement is "to, by using" as outlined by Crawley (2009).

- To increase, through intuitive and efficient models, efficiently and at reasonable cost to the government, the situational awareness of tactical decision-makers acting on mental models of the terrain

- By producing geospatial information, which conforms to industry standards for interoperability and is highly accurate and of high resolution geospatial products. Produced through remote sensing and collection, generation and processing, management, analysis, visualization, and dissemination.
- Using the "Army Geospatial Enterprise"

- To increase
- (through intuitive and efficient models)
- The situational awareness (of tactical decision-makers)

- Acting on mental models of the terrain
- By producing geospatial information
- (highly accurate and high resolution geospatial products)
- Produced (through remote sensing and collection, generation and processing, management, analysis, visualization, and dissemination)
- Using the Army Geospatial Enterprise

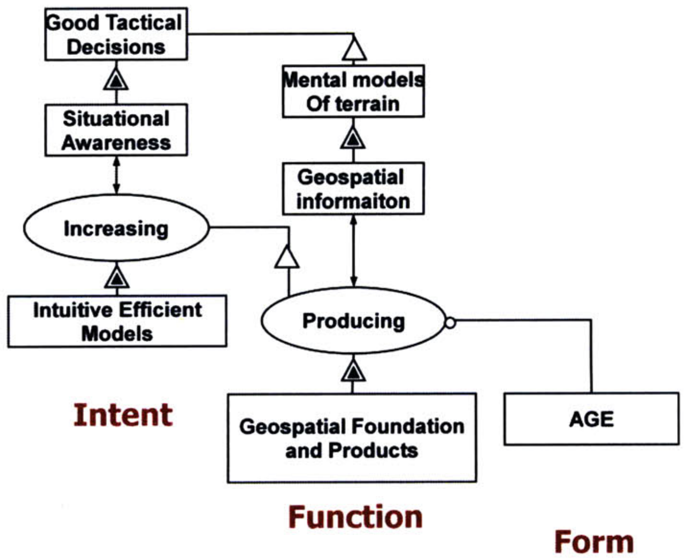


Figure 3-6: Enterprise Problem Statement Structure

The enterprise problem statement, as shown in Figure 3-6 captures the needs that the enterprise is addressing, and the general concept by which these stakeholder needs are satisfied. As the architecture is fully developed, the Object Process structure of Figure 3-6 can be expanded to include the form and function of the AGE solution

3.3.2 Goal Prioritization and Metrics

The vast majority of enterprise energy is focused on increasing the geospatial information capability for the tactical decision maker. The goal of sound tactical decisions based on terrain knowledge drives all aspects of the enterprise. The premise that this information is increased through standards and synchronization of geospatial capability within the Army drives the effort across the enterprise. There is an overall lack of secondary and tertiary prioritization with the enterprise. For example, there is little weight given to the information requirements of National Level decision makers: the AGE does not directly consider those needs.

There is an overall lack of metrics within the current state of the enterprise. All data about the performance of brigade terrain teams, for example, is kept at the brigade level and not collected or aggregated across the enterprise. Performance is only tracked anecdotally during discussions among senior leaders and geospatial governance elements. This lack of metrics in the current state architecture reduces the ability to generate value and make informed adjustment to the AGE.

3.3.3 Ensuring Satisfaction of Essential Needs

In order for the problem statement to be complete, all of the key needs of the priority stakeholders must be met. For the stakeholders to agree on the value proposition of the enterprise, at least some of the needs of all of the stakeholders must be met, and most of the needs of the primary beneficiary. The tactical decision makers must have their geospatial needs met, or they will seek geospatial information from other sources. There are some small examples of this in the current state enterprise. For example, many units are not satisfied with the capability of the Geographic Information System (GIS) that is fielded to them by the Program of Record (POR.) So units will take discretionary funding and procure additional geospatial capability outside of the AGE systems provided. This circumvention of the enterprise occurs because not all of the essential needs were met within the enterprise solution. As the future state architecture candidates are evaluated in chapter four, meeting the essential needs will be very important to enterprise success.

3.4 Value Delivery - Enterprise Architecture "As is" View Descriptions

The value delivery portion of the framework is how the value proposition is fulfilled in practice. Value delivery occurs when all of the parts of the enterprise function. The degree of synchronization among the functions of the enterprise contributes significantly to realized, or unrealized, value creation by the enterprise.

As discussed in the chapter introduction, the view descriptions provide a very effective way to understand the value delivery of the enterprise today. Each view has both structure and behavior, both are important to properly characterize the perspective on the enterprise that the view is enlightening.

Views	Description
Strategy	*Goals, vision and direction of the enterprise, including business model and competitive environment.*
Policy/ External Factors	*External regulatory, political and societal environments in which the enterprise operates.*
Organization	*Organizational structure as well as relationships, culture, behaviors, and boundaries between individuals, teams and organizations.*
Process	*Core processes by which the enterprise creates value for its stakeholders.*
Knowledge	*Implicit and tacit knowledge, capabilities, and intellectual property resident in the enterprise.*
Information	*Information needs of the enterprise, including flows of information and systems/technologies for information availability.*
Product	*Products produced by the enterprise for use by its stakeholders.*
Services	*Services of the enterprise, including services as a primary objective or in support of product.*

Table 3-3: Description of the Eight Views (Rhodes, Ross and Nightingale 2009)

3.4.1 Strategy View

The strategy view captures the goals, vision, and direction the enterprise is pursuing. The current AGE strategy outlined by the GGB and the GIO has several dimensions. The AGE has aligned itself with the battle command transformation efforts. The geospatial problem lies at a triad between the G2 (Army Deputy Chief of Staff for Intelligence), the Chief of Engineers, and the G3 (Army Deputy Chief of Staff for Operations) with emphasis on battle command and providing value to operations. The primary beneficiary is the maneuver commander, not the intelligence analyst. The battle command function concept requires alignment with C2 systems, not only the DCGS-A intelligence system that the terrain teams use to analyze the terrain and produce products.

The current strategy of the Army Geospatial Enterprise is to identify gaps in the current value delivery of geospatial services. Once these gaps are identified and evaluated, solutions to the gaps are proposed. The solutions have implications across many stakeholders of the AGE, so coordination through planning conferences and governance board meeting (GGB) are required to push the changes necessary to close the identified gaps.

The quantification of strategy performance through enterprise metrics is not well defined in the current AGE architecture. Since geospatial operations are decentralized among the brigades, there is not consolidation of terrain team performance. Measurement of value delivery is done anecdotally by experienced geospatial warrant officers. The only part of the enterprise that is measured extensively is the system development and fielding portion. The program office that fields the geospatial information systems to the terrain teams and geospatial units across the Army must adhere to cost and schedule performance metrics as defined by the acquisition program management office.

3.4.2 Policy / External Factors View

The AGE seeks to implement its strategy through policy adoption and standards enforcement. In order to achieve geospatial synchronization, the AGE defines standards for the battle command programs (PORs and non-PORS). Since these constraints have the possibility to add time and cost to program development, there is potential for conflict among these stakeholders. In order to reduce the tension, commercial and industry best practices dominate the standards and interoperability policy decisions.

The pace that standards working groups and policy boards can generate sustainable community agreed upon solutions is critical for increased investment toward interoperable systems. Many of the enterprise stakeholders, particularly the industry suppliers, will be reluctant to implement significant changes to their products or services until the policy environment reaches stable plateau. The implication is that policy change can occur too quickly, denying stakeholders stable intermediate states, or too slowly, reducing the adoption of interoperability as desired by the enterprise strategy.

3.4.3 Organization View

"Some units have Terrain sections with S3/G3, others with S2/G2. Big army needs to make a decision if we will be part of the engineer community or the intel community." Terrain Team Noncommissioned Officer in Charge, Army Geospatial Survey

There is a lack of consistency among the organization of the terrain team within the brigades across the Army. Figure 3-7 shows the breath of terrain teams across the force structure. There are approximately 70 brigade level geospatial terrain teams. Each of these teams has between four to five Soldiers. The team typically works for the S3, Operations chief, the Engineer, or the intelligence section.

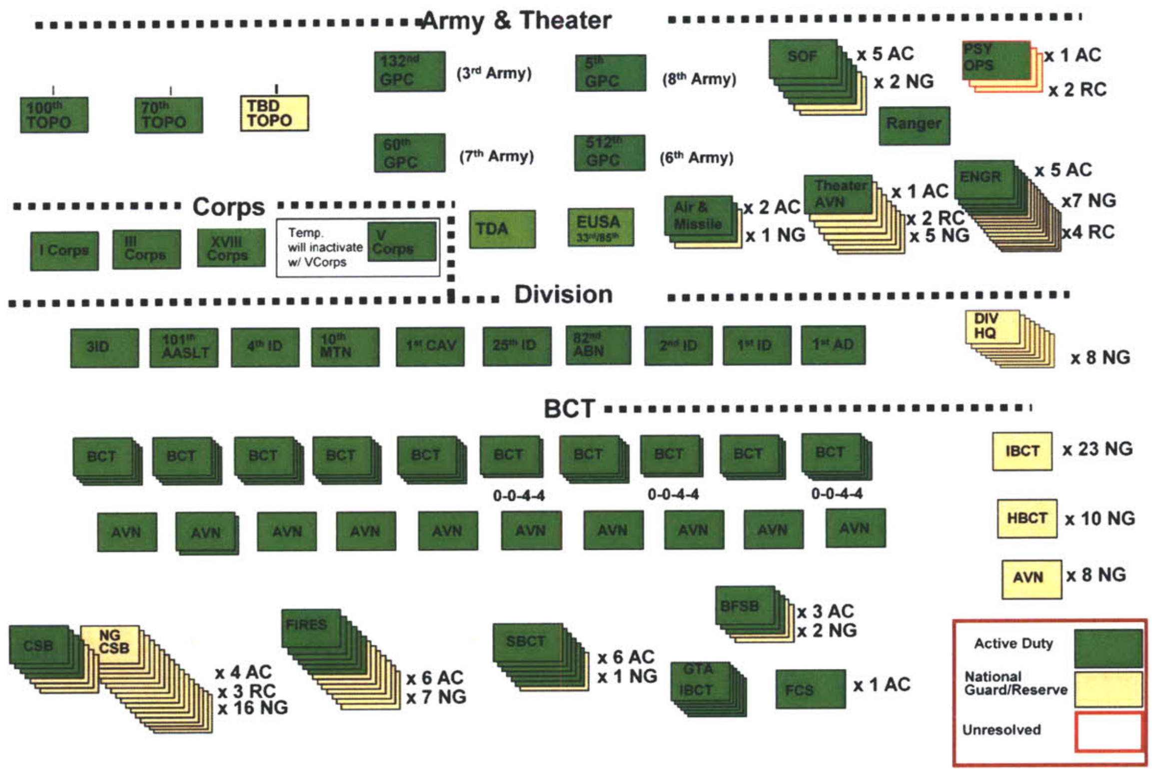


Figure 3-7: Geospatial Force Structure

The organization of the terrain elements inside the Army has evolved with the Army transformation effort. Prior to the recent Army transformation, terrain assets lived organically in functional organizations, topographic battalions. The assignment of Soldiers to terrain teams is done in the typically, one size fits all Army Human Resources Command manner. The assignment officer is forced to fill slots with the Soldiers that are available within each assignment window, therefore it is more difficult to place the right talent in the right brigade terrain team than under the old centralized Corps Topographic Company structure. This increases the variance of capability between the terrain teams, potentially leaving some brigades lacking in geospatial capability.

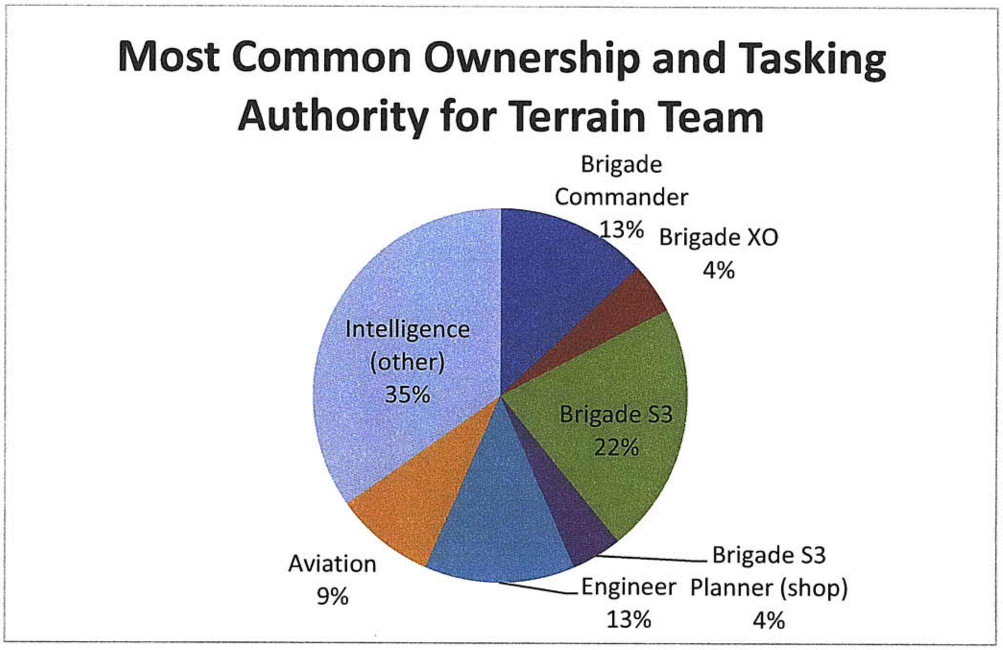


Figure 3-8: Common Reporting Structures for the Terrain Team Organization

The organization directly impacts the knowledge and process view, and indirectly impacts each of the other views. The organization of the brigade Tactical Operations Center (TOC) impacts the flow of geospatial information to all Warfighting Functions. Figure 3-9 depicts the information flows.

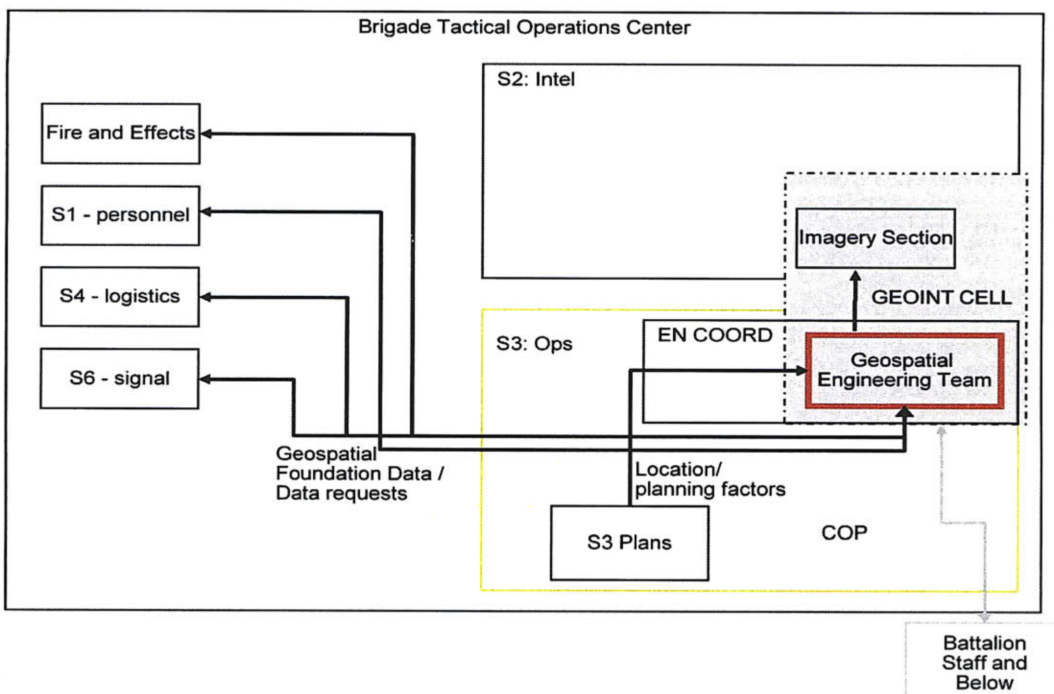


Figure 3-9: Generic Brigade TOC Organization and Geospatial Information Flows

3.4.4 Process View

"There were no methods to capture geospatial data from various organic sources within the Corps unless I manually hunted for them and jammed them into my database. For instance the C5 guys had a list of hospitals on a spread sheet with some information that I needed to fill in holes in my urban database. If I had not gone to them and discovered this spread sheet I would never have known about it. Many such examples happened throughout the operation." Terrain Geospatial Technician, Army Geospatial Survey

"Most of the terrain teams in theater were [in one place]. Data was not being disseminated down to the lower levels, specifically the battalion and company level. Most missions at those levels were still relying on the old NGA paper TLM's, which could be mass ordered with a DLA account." Terrain Team Noncommissioned Officer, Army Geospatial Survey

The generic value stream of geospatial information is given in Figure 2-11, but this stream only implies all of the interactions, feedback elements and iterations within the process. Mission planning, rehearsal, and execution are all constantly intertwined with geospatial operations. This continuous, iterative process more closely resembles a cycle, than a linear value stream. As the "GEOINT Cycle" progresses, value is added to the information provided to the tactical decision makers.

Prior to the proliferation of geographic information systems into the Army, most of the processes associated with Army geospatial activities occurred in several buildings in the Washington DC area. The building layout mirrored the value stream in an assembly line format reminiscent of a Henry Ford factory. Cartography, draft, layout and lithography were all housed under the same roof, simplifying the interactions between tasks on the value stream, but delivering static maps in a "one size fits all" fashion across the Army. (Escape Maps 2010)

Today, the Army Geospatial Enterprise is distributed across the force and around the world. The generation, storage, production and display of map and geospatial information can occur down to the vehicle level, or consolidated at Nation level organizations.

3.4.5 Product and Service View

There are two categories of products within the Army Geospatial Enterprise. First, there are the systems that collect, process, store, disseminate and visualize geospatial information. Second, there are the tactically relevant sets of geospatial information, typically displayed on a map. These products consist of information obtained from higher echelons and passed through to tactical decision makers, as well as, information generated at a lower echelon, as locally developed products.

3.4.5.1 Army Geospatial Enterprise "System" Products

The product, or system, architecture of the information systems produced by the AGE and its partners is controlled, at least in part, by the Chief Information Officer (CIO) of the Army. The Army CIO has responsibility for all of the governance, management and delivery of information technology programs within the Army. This centralized IT approach includes the IT components of Army Battle

Command and thereby the Army Geospatial Enterprise as well. (Department of the Army Chief Information Officer/G-6 2009)

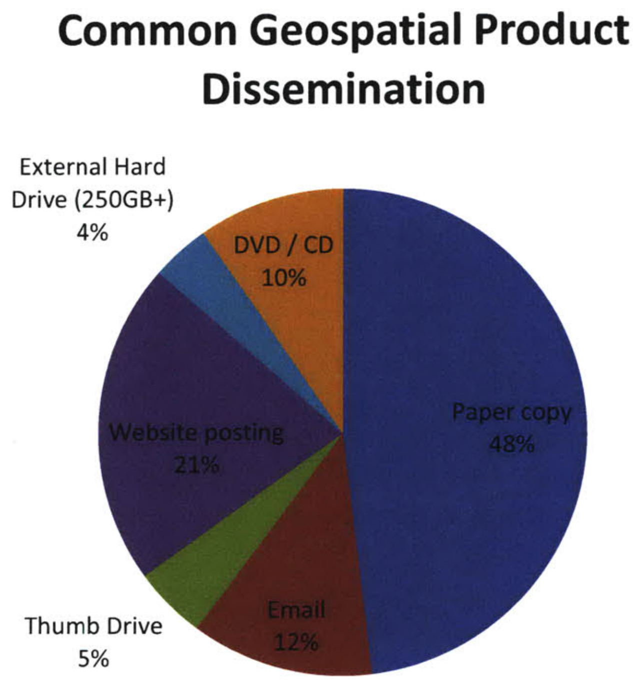


Figure 3-10: Dissemination Media Types of Geospatial Products

3.4.5.2 Army Geospatial Enterprise "Information" Products

The enterprise produces geospatial information products at many different levels. The national level agency charged with the production of geospatial information is the National Geospatial-Intelligence Agency. They produce geospatial products for each of the military services, the Intelligence Community (IC), and some civil applications where possible. Some examples of common information products that are commonly used within the AGE are Topographic Line Maps (TLMs), Controlled Image Base (CIB) imagery, Vector Interim Terrain Data (VITD) and other basic NGA terrain products. The Army Geospatial Center, is the primary point of geospatial production and synchronization within the Army.

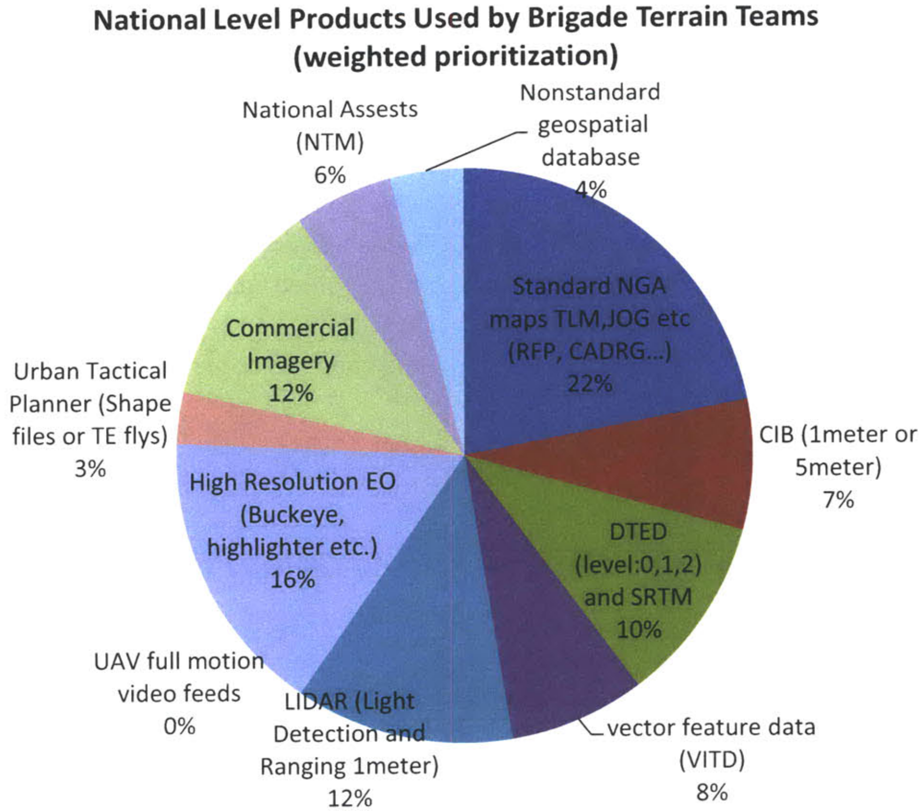
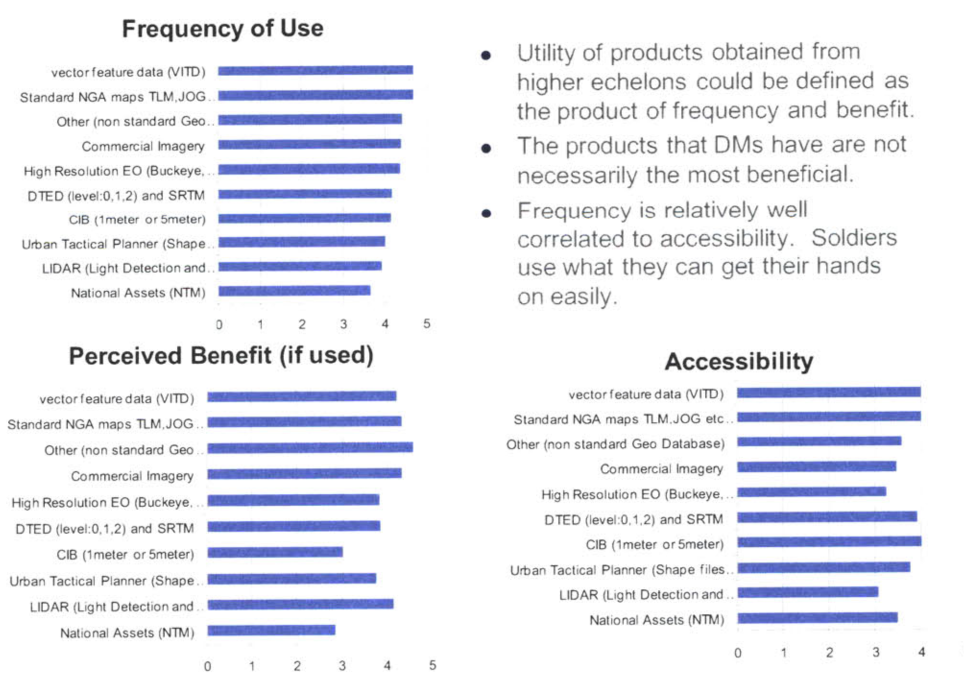


Figure 3-11: Information Products Used within the Enterprise



- Utility of products obtained from higher echelons could be defined as the product of frequency and benefit.
- The products that DMs have are not necessarily the most beneficial.
- Frequency is relatively well correlated to accessibility. Soldiers use what they can get their hands on easily.

Figure 3-12: Data Source Utility to Geospatial Engineering Teams

3.4.5.3 Product Architecture Alignment

There must be architectural alignment between the systems and in information products of the enterprise. For example, the data formats that a system requires must be aligned with other similar systems as well as the standards to which the information providers are producing. In the recent past the system architecture has forced the information product standards to adapt, causing unnecessary duplication, redundancy and stovepipes. The problem is exacerbated by length of system lifecycle, so legacy system data formats must be supported through a long phase out and decommissioning period. A simple example of this is the number of file formats that basic NGA map data must be produced in, from ADRG, CADRG, RFP, Mr SID, BMP, etc, etc, supporting hundreds of geospatial information systems developed from the 1980s to today.

There is a significant effort currently underway within the AGE to align the products and services view of the enterprise.

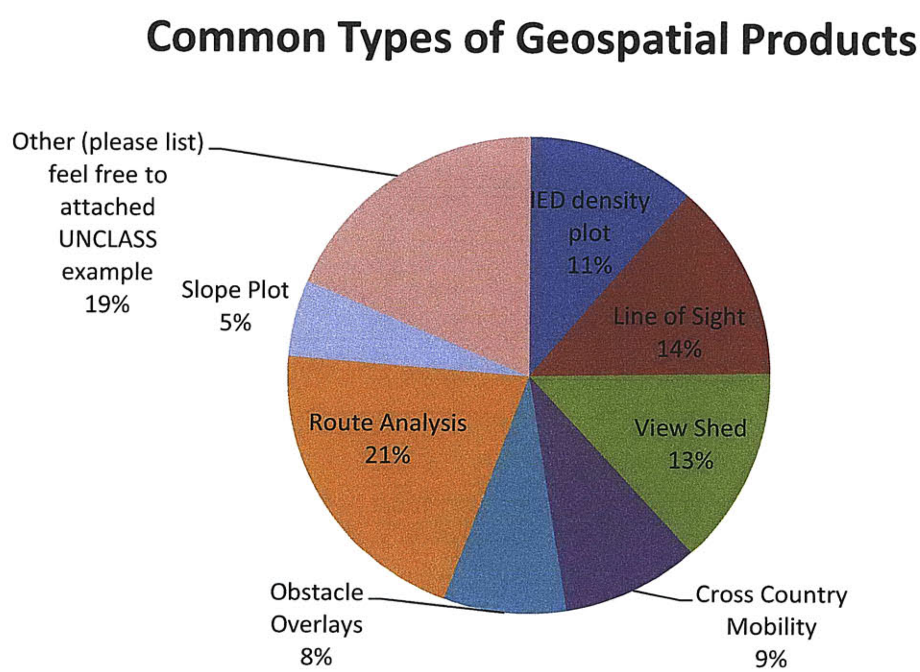


Figure 3-13: Frequency of Geospatial Product Types

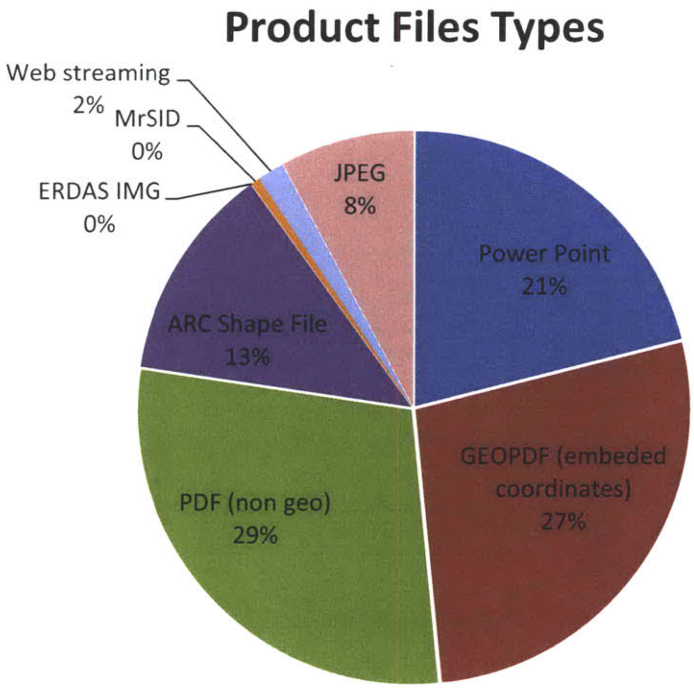


Figure 3-14: Frequency of Product File Types for Dissemination

3.4.5.4 Service-Oriented AGE Delivery

Some of the historical products of the enterprise are transition to services. For example, instead of providing a Soldier with the information system (a product) and a geospatial data external hard drive (a product) a service-oriented architectural approach is emerging. This approach is still new within the current state architecture. Web services are typically constrained to file sharing and transfer with only a few applications of tactical streaming map servers.

3.4.6 Knowledge

"The biggest success story was the fact that my Terrain team introduced a FOB's worth of units to the benefits of incorporating Geospatial products into their mission planning. Everyone that came into my shop, I educated them on the uses and benefits of different products and made every effort to show them ways they can access websites with products already made or contacts where they can ask for things that we did not make, though most times I ordered these myself" Terrain Team Noncommissioned Officer, Army Geospatial Survey

"Most of the other soldiers in our unit didn't really know what we do. They confused us with a print shop and we always asked if we laminated things." Terrain Team Specialist, Army Geospatial Survey

One way to observe the knowledge view of the enterprise is to inspect the interactions of the value stream within the cognitive domain, tracing what type of information is interacting with each member of the enterprise. In the current state, the knowledge in the enterprise is held primarily with a small number of experts in each of the terrain teams. The enclave of knowledge increases to the process and information stovepipes in the broader battle command enterprise.

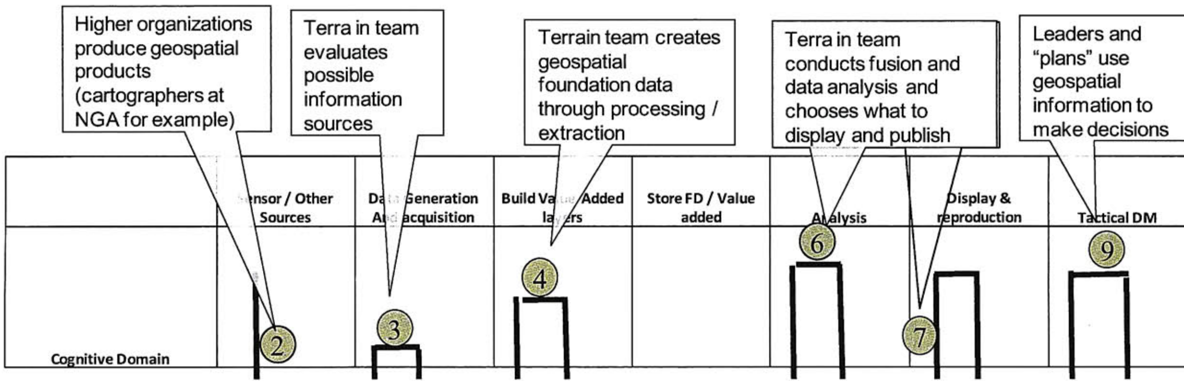


Figure 3-15: Cognitive Domain of Value Steam Defining Knowledge View

The cognitive activities are dominated by the terrain team and geospatial experts, only four to five individuals within the brigade. Because the geospatial tasks are concentrated, the training education and expertise surrounding terrain is also limited to these pockets of highly capable analysts. There are some staff planners that educate themselves on the capabilities of geospatial information, learning to manipulate and apply these techniques to gain better battlespace awareness, but this group represents a minority of the tactical decision makers. Since there is very little institutionalized opportunity for the typical Soldier to gain these skills, ignorance of the benefit of geospatial information is pervasive.

3.4.7 Information and Information Technology

The information portion of the view is discussed extensively in section 2.4.1, and the information domain is critical to the performance of the AGE. The Army Geospatial Enterprise produces an information system as a product of the enterprise to be used by the Soldiers and civilians that deliver geospatial information across the enterprise (the IT systems that produce GIS systems). But the enterprise also uses information technology within the enterprise as well, to convey process and knowledge information, as well as aid in the development of new geospatial IT systems. The development of standard data models, change formats, and reduction of proprietary file types seeks to reduce the information technology silos that exist within the current architecture. Currently, much time is spent converting file types in order to provide the geospatial foundation data to non-interoperable battle command systems.

3.5 View Interactions

The strongest view interactions occur between the process, organization and knowledge views. The tasks that each Soldier operating as part of the AGE or at the AGE boundary are extremely significant to the force structure of those units as well as the knowledge required by those individuals for successful task completion.

Another interesting view interaction is between the policy and strategy views. In the AGE, many of the strategic goals of the enterprise are achieved through policy. "The AGE described in this CONOPS is not a new program or system. It is a set of Army policies, directions, and standards that will be implemented by existing and future BC Programs, and BC non-Programs, to ensure migration to and establishment of a standard and sharable GF" (TRADOC Capability Manager Geospatial 2009). In turn, the ability of policy intervention to achieve the strategic goals will shape future strategy. For example, if the standardization of data models through acquisition policy did not achieve information synchronization, a new strategic approach would be sought to align the battle command system development efforts across the Army. In this way iteration between policy and strategy is essential to success

3.6 Modeling the AGE Dynamics at the Enterprise Boundary

A model, capable of simulation, is one method to understand how the design variables of the enterprise yield the desired attributes of the stakeholders. A model encompassing all of the stakeholders (internal and external) of the AGE could be developed in order to show all of the dynamics within the enterprise, but this model would be quite complex. Another approach is to model only the necessary elements that provide insight into the areas of the enterprise that are of most interest. The work of this thesis is focused on how the AGE interacts with the lowest echelons of the Army force structure, how geospatial information moves about the brigade level and below, and how this information informs tactical decision making at the dismounted Soldier level.

3.6.1 Description of the model

In order to model the current state architecture and the future state in chapter four, System Dynamics (SD) modeling will be employed to understand the information dynamics of the AGE. The goal is to gain insight into the system level effects of changing the "knobs" discussed above within each view of the enterprise, as well as the complex behavior that results due to the interactions of the views as stated in enterprise architecture framework discussion in section 3.1.1. System dynamics is an appropriate choice of modeling tool due to its versatility to a wide set of applications.

System Dynamics is a model method developed by Jay Forrester at MIT in the 1950s. The method divides the world up into stocks and flows. A stock is anything that accumulates past events, an integral or state variable. A flow is a change to a stock, a rate or derivative. System Dynamics models changes to stocks by flows over some time period. A typical analogy for describing stocks and flows is to equate them to a bathtub. The water in the bathtub at any given moment in time is a stock. The water flowing from the facet and the water running out of the drain or the flows that define the amount of water in the tub, given some initial condition. For the model of the Army Geospatial Enterprise, an aggregate of Soldier perception of the benefit of the geospatial information is the stock, and the flow is the addition of utility from new information, or the decrease in utility as the information deteriorates over time.

In order to best understand the effects of changes in the Army Geospatial Enterprise, a simple model of the benefit and flow of geospatial foundation data throughout the brigade and below is developed and simulated. The model has three primary feedback structures and four other flow structures of interest.

The key stocks within the model all attempt to measure the utility of the geospatial database at each level of the brigade. This aggregate measurement makes several simplifying assumptions:

- The geospatial databases are the same at each echelon. For example, each battalion in the brigade has the same geospatial foundation data. This can be different from the foundation layer at the brigade or company level, but each of the three to eight battalions in the brigade are equivalent.
- The geospatial foundation data utility is only loosely related to the physical storage size of the database. For example, the utility of database with zero bytes of information is also zero, but two databases of equal physical size, 100GB for example, may not have the same utility. The utility is based on the quality of the information in the database, and the mission information requirements levied against the information.
- The utility of the geospatial foundation layer is inversely proportional to the age of the information; this represents a decrease in quality of the information over time. The constant of proportionality is dependent on the nature of the mission and the dynamics of the terrain that the mission operates upon.

The remaining structure of the model attempts to capture the dynamics of the enterprise effects on geospatial foundation data utility over the course of a notional 450 day mission. There are several key points of time within the model representing activities of the mission cycle.

- Day 0: The brigade is located at home station. A mission is received from division level. Mission planning begins with no prior knowledge of the terrain.
- Day 15: The unit deploys to the theater of operations. The geospatial data foundation layer initialization process is complete (at whatever state the initialization has progressed to) and operations begin.
- Day 330: In the base case and Epoch B and C discussed below, this is the only instance of a change of mission issued to the brigade. For the intervening 315 days, the unit had been operating continually over the same terrain with roughly the same mission set.
- Day 331: A new unit begins operations on the terrain. It has received information briefings and data sets from the unit relieved, but there has been significant loss of the total understanding of the terrain due to the change in personnel, misplacement of information, and lack of experience with the mission.
- Day 450: The simulation concludes and measures the utility of the geospatial foundation layers averaged throughout the simulation. The five layers measured are each stock of the utility of the foundation layer at each level of the brigade: the terrain team, the brigade staff, the battalion, the company, and the individual or platform, which includes the gained experiences of the individuals from operations.

3.6.2 Feedback structure of the base model

The dynamics of the Army Geospatial Enterprise at the brigade level are modeled with causal loop diagrams. Three causal loops described below are the three primary drivers of the model behavior and attempt to approximate the geospatial information dynamics within a brigade. Each feedback loop is discussed and described in detail. The mathematical formulations of the model are found in Appendix C.

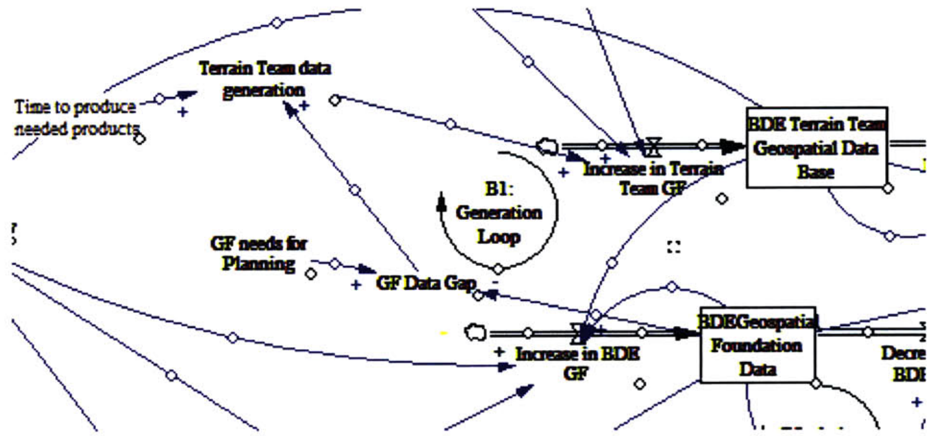


Figure 3-16: Data Generation Loop

3.6.2.1 Balancing Loop #1: The Terrain Team Data Generation Loop

This loop consists of the brigade terrain team producing a new product. The team then distributes this new product to the rest of the brigade staff (or the staff section that requested the product) this increases the overall utility of the geospatial foundation data on the staff. The increase in the geospatial foundation data within the brigade staff decreases the geospatial foundation data gap, which then decreases the amount of data that needs to be generated by the terrain team. This balancing loop is a goal seeking behavior loop that attempts to seek the goal of the total need for geospatial planning, which is assigned to a value of one within the model.

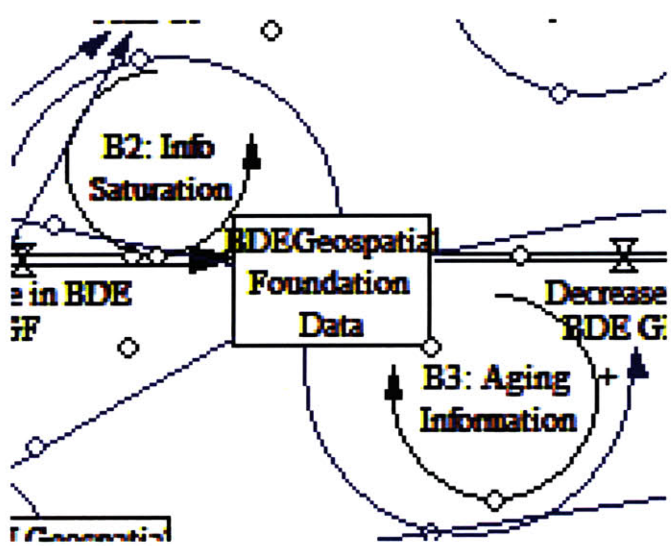


Figure 3-17: Balancing Loops of Benefit of Geospatial Foundation Data

There are two more primary feedback structures in the base model. This structure is repeated for each hierarchical level within the model, the battalion level, the company level and at the individual or platform level.

3.6.2.2 Balancing Loop #2: Information Saturation loop

This loop is a very simple loop that captures the idea that the more geospatial foundation that any entity has within the brigade, the less "new" information, with possible new benefit, that any interaction with another entity will have. One can think of it this way, if a company commander did not know anything about the terrain that he was about to operate within, he would gain much more benefit from any amount of information that he could receive from any source. But if the same company commander had operated within the terrain for a year, had analyzed all of the maps, gathered all of his own new information and was very familiar with the terrain, there is much less of a chance that a geospatial data product would provide as much, if any, benefit.

3.6.2.3 Balancing Loop #3: The Aging Information Loop

Again, this loop is very simple structurally within the model. It captures that idea that the more geospatial information that an entity has about the terrain, the more likely that changes to the terrain will decrease the benefit of the geospatial foundation layer. This idea can be observed at the extremes. If a commander knew absolutely nothing about the terrain of a location, any changes within that location would not change the level of knowledge, which the commander possessed. In the same way, if it were possible for a commander to know literally everything about the terrain of a location, any change, no matter how small, would decrease the benefit of that knowledge. This balancing loop relies on the premise that the terrain of the modern battlefield is dynamic, therefore there is a "hole in the bucket" of information benefit. The utility of the geospatial foundation layer degrades over time as the information ages.

3.6.3 Other Structural Elements of interest

In order to represent the other data flows acting on the system, four other primary structures are used: data initialization, data from higher, learned terrain data from operations, and change of mission. Each of these exogenous factors represents changes to the information status of the brigade. The following table depicts the model parameters that establish the structures described below. Because many of these values are dimensionless and aggregations of the benefit received from many different map products and services, there is not as much physical meaning to the numerical value. The baseline model parameter values tune the simulation to the current state enterprise structure and performance within approximate current state environmental operating conditions.

Table 3-4: Geospatial Enterprise Model Parameters

Name of Model Parameter	Baseline Value
mean benefit of updates	0.003 dmnl / day
st dev of updates from higher	0.04 dmnl / day
time to produce needed products	200 days
GF needs for planning	1 dmnl
Fraction of geospatial utility filtered down	50%
time to initial the GF	10 days
Deployment Time	15 day
time to update GF from higher	40 days
OPTEMPO	0.001667 dmnl / day
Time constant for degration of GF	50 days

3.6.3.1 Data Initialization Process:

The data initialization process occurs over the first 25 days of the simulation. It begins with an "initial data provision from higher" during which the brigade terrain team receives a push of data from the division level. Also at this time the terrain team would seek out other data sources through web searches, NGA liaisons, DLA catalogue and any other available sources. This search would typically occur at home station just after the brigade received the deployment order, but it could also occur within a deployed environment if a unit is reassigned to another geographic area. The brigade terrain team then evaluates the data and determines what should be part of the geospatial foundation data at the staff level, company level and on the platforms. The storage capability of digital data at each echelon is currently a consideration for the team. The foundation layer, which will become the basis for the brigade common operating picture (COP), is a fraction of the possible data that the terrain team has assembled. Over a period of time before the equipment is packaged for shipping, the terrain team would initiate a distribution of the geospatial foundation. Once the brigade is deployed into action, the data transfer continues, but the ability to quickly propagate the large volume of data will not be as easy as it was at home station.

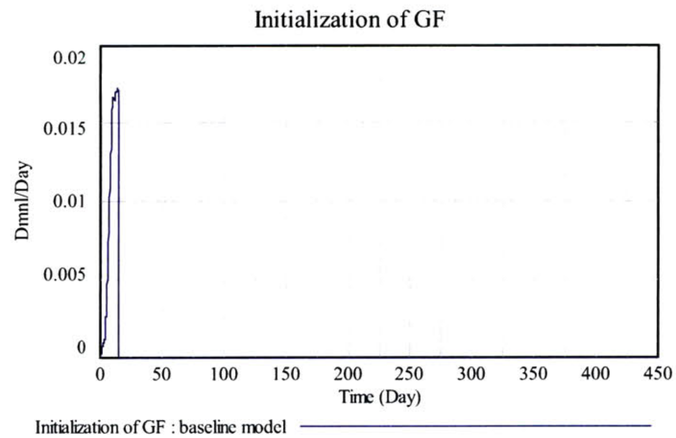


Figure 3-18: Data Initialization from Terrain Team to each Echelon

3.6.3.2 Data from Echelons Above Brigade

All of the echelons above brigade all of the way up to National level data producers, will continue to create new geospatial foundation products and update the existing data. These updates occur as a result of many differing requirements processes. The order of importance for new data collection, processing and map production is determined at levels so far above the brigade that an approximation of the delivery of these products, at an aggregate level, is that they are random. Any day during a deployment has some probability that some higher level data producers will publish a new foundation data product within the Area of Operations (AO) of the brigade. It is also random how beneficial that new update will be to the understanding of the terrain. For example, a high quality, high resolution data product might be delivered directly over the most contentious portion of the city that the brigade is currently operating within. Such a product might significantly increase the benefit of the geospatial foundation layer to tactical decision making. A new low resolution elevation model, while useful may not be as much of an increase in the overall utility of the dataset as a whole. Therefore, the effectiveness of data pushes from higher levels is "noise" function, adding to the benefit of the GF at random times and random utility amplitude.

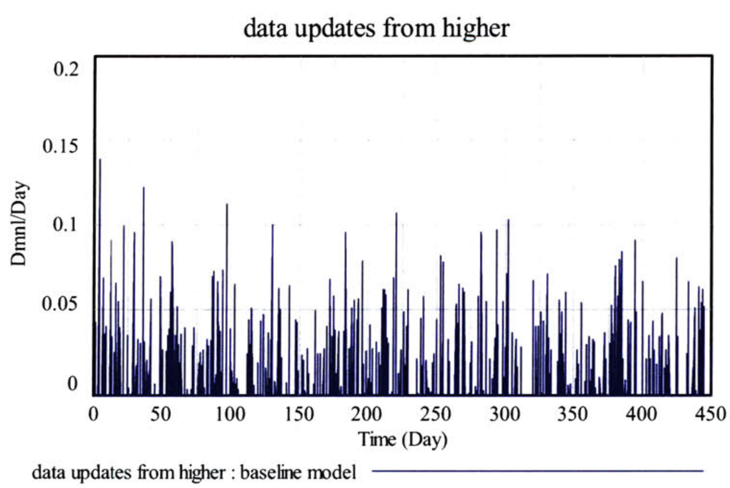


Figure 3-19: Stochastic Nature of Data Updates from Superior Unit Levels

A simplifying assumption is that data sets and products generated at levels higher than brigade are filtered down to lower levels in a Poisson process. This represents NGA producing an updated map over the Operations Area of Brigade. One could argue that given the requirements of the generation process, this process should not have that high a degree of randomness. But given the number of disparate data sources, the addition of data to the Geospatial Foundation is as likely immediately following an addition as it is just prior to receiving an addition. Therefore a "memory less" distribution is appropriate. One could imagine that when NGA updates it 1:100k topographic line map, another independent event, such as Digital Globe publishing a new frame of GeoEye commercial imagery over the same location could occur. Therefore the Army Geospatial Enterprise could influence the rate of the data generation and delivery process from its supplying stakeholders, but may not be able to coordinate the process very well between the stakeholders.

The majority of the new information that can be obtained would have only a nominal effect on the overall total utility of the geospatial information continued in the terrain team's assets. Occasionally, there might be an externally produced product that would align perfectly with the informational needs of the terrain team; these items would increase the total utility of geospatial information more substantially.

3.6.4 Learned Terrain Data from Operations

As Soldiers enter a new Area of Operations (AO) they desire to explore the terrain within which they will operate. This is typically done through a series of reconnaissance missions, where the unit leadership surveys the terrain to assess its military effects. They will then use this information to inform their planning cycle as well as during operations to make educated impromptu tactical decisions. When Soldiers first arrive, the only information they have about the terrain is from their initial push of geospatial foundation data. They may question the quality of the data, but they do not have another source as they begin their occupation of the AO, unless they are taking over from a unit that has already been in the battle space. Since the Soldier has no experience of the terrain, the benefit of the geospatial information from experience is zero. As they operate in the AO for a longer period of time the understanding of terrain from experience surpasses the benefit of information from the geospatial foundation layer. This is equivalent to a local Bostonian trusting their own knowledge of the back streets of Cambridge over the navigation directions that the GPS is providing. Unless the individual has reason to believe that the geospatial foundation layer has higher information quality than their own experience (for instance a construction update report that may be useful for the local Bostonian), he will rely more on his own experience and less on the foundation data. This learning through experience is "learning the hard way" since it often involves getting vehicles stuck down an alley that is not maneuverable, or reaching a bridge that no longer exists. This information is of high quality since it is verified by Soldiers on the ground. It is often most meaningful to Soldiers conducting operations.

The idea of learned terrain data from operations is captured in the model of the AGE boundary. This is critical because this information of the terrain can be used to update the geospatial foundation layer within the Every Soldier as Sensor construct. This is currently not heavily implemented in the AGE architecture. It will be discussed for its future architecture potential in section 4.4.1.

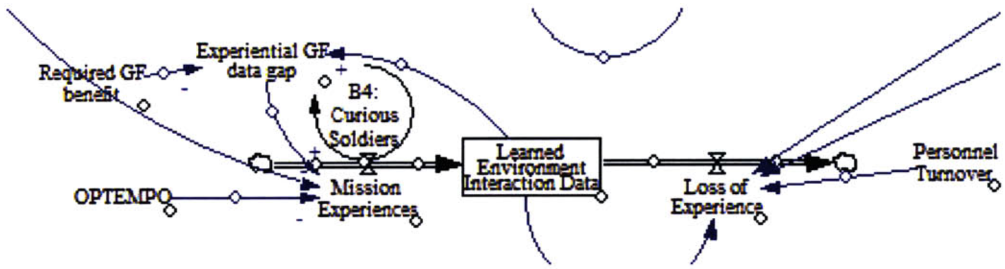


Figure 3-20: Learned Terrain Data from ESS Model

In the current state architecture, terrain information is typically stored locally in notebooks or excel spreadsheets. This is beginning to change with the deployment of the TIGR system, discussed more in section 4.9.2.

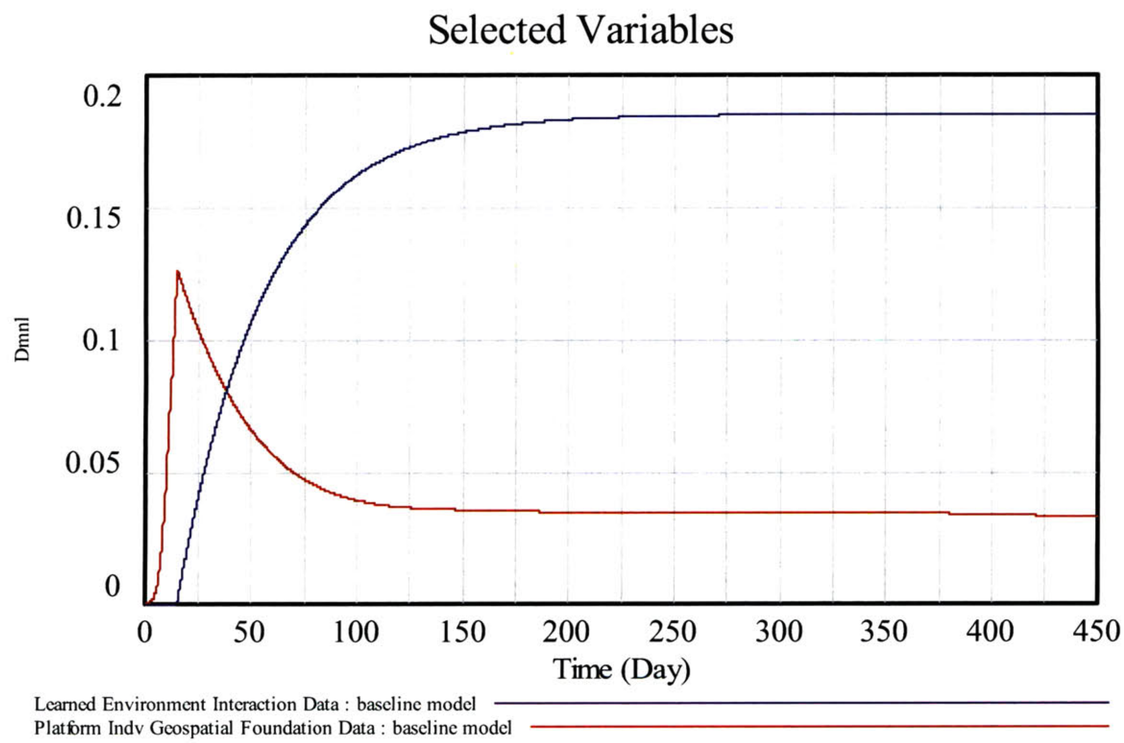


Figure 3-21: Baseline Simulation of Geospatial Foundation Data at the Individual Level and GF Experience Benefit

The graph of Figure 3-17 depicts the relative benefit from geospatial foundation data provided by higher echelons (in red) and the benefit from operating on the terrain and learning the geospatial information through experience (in blue). The point at which the two levels cross is the point at which a Soldier has equal probability to gain more benefit from the digital geospatial foundation layer as he does to gain benefit from his experience. A Soldier would be indifferent to trusting his map over his "gut feeling" if the two information sources conflicted. The point at which this transitions, if it ever transitions, is dependent on many factors, but primarily the OPTEMPO of the missions (how often they have maneuvered on the terrain) as well as the size of the AO.

3.6.5 Change of Mission – Relief in Place, Transfer of Authority (RIP TOA)

A final structural element to add to the baseline model is the effect of a change in mission to the unit on the geospatial information foundation layer. A change of mission is a change in either the tasks the unit is performing or the location, or AO, over which the unit operates. In the case of ongoing operations within a theater of operations, such as Iraq or Afghanistan during Operation Iraqi Freedom and Operation Enduring Freedom, a change of mission typically occurs with a Relief in Place and Transfer of Authority. A Relief in Place (RIP) is when a new unit falls in on the same area that the original unit is operating in. A Transfer of Authority (TOA) is the moment in time that the RIP is complete and the new unit is responsible for the operations of the AO. Very soon after a TOA the old unit will vacate the area and move on to its next mission or operation. Since the terrain changes, most of the information that Soldiers have been given, and have gained through operations, is no longer valuable. There is some residual value based on general experiences with the terrain, but these are typically minimal depending on where the next area of operations is located. The model approaches this problem by "pulling" the plug out of the stocks of the geospatial information. For purposes of the simulation, the RIP TOA data is on day 330 of the simulation.

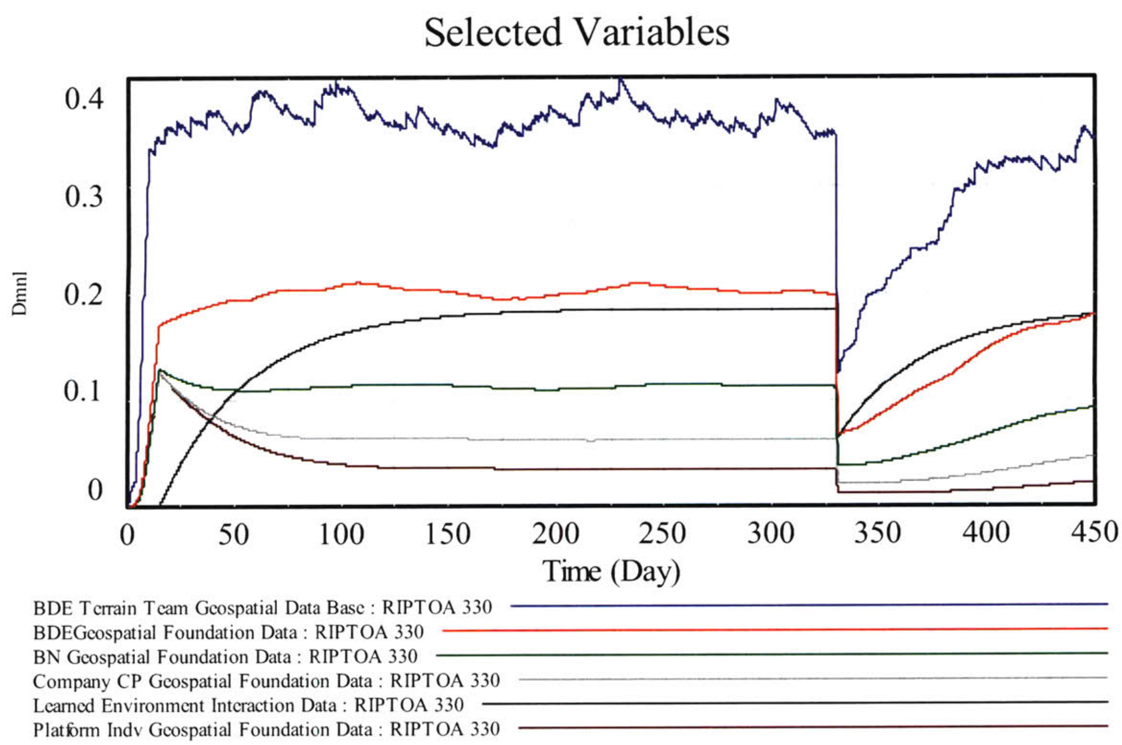


Figure 3-22: Baseline Simulation of Geospatial Foundation Data with RIPTOA

Simulation of the baseline model parameters:

With all of the above structural elements combined into a single baseline model, the System Dynamics model can be used to understand the impact of changes to the input, or design variables, of the enterprise. It is helpful to note here again that this is a very low fidelity model which contains many simplifying assumptions. Values are relative and represent approximations of modes of behavior, providing order of magnitude measurement. But in the case of a first cut at a high level enterprise approach, this level of detail allows for the model to be easily understood and manipulated, while still providing insight into current and future state dynamics.

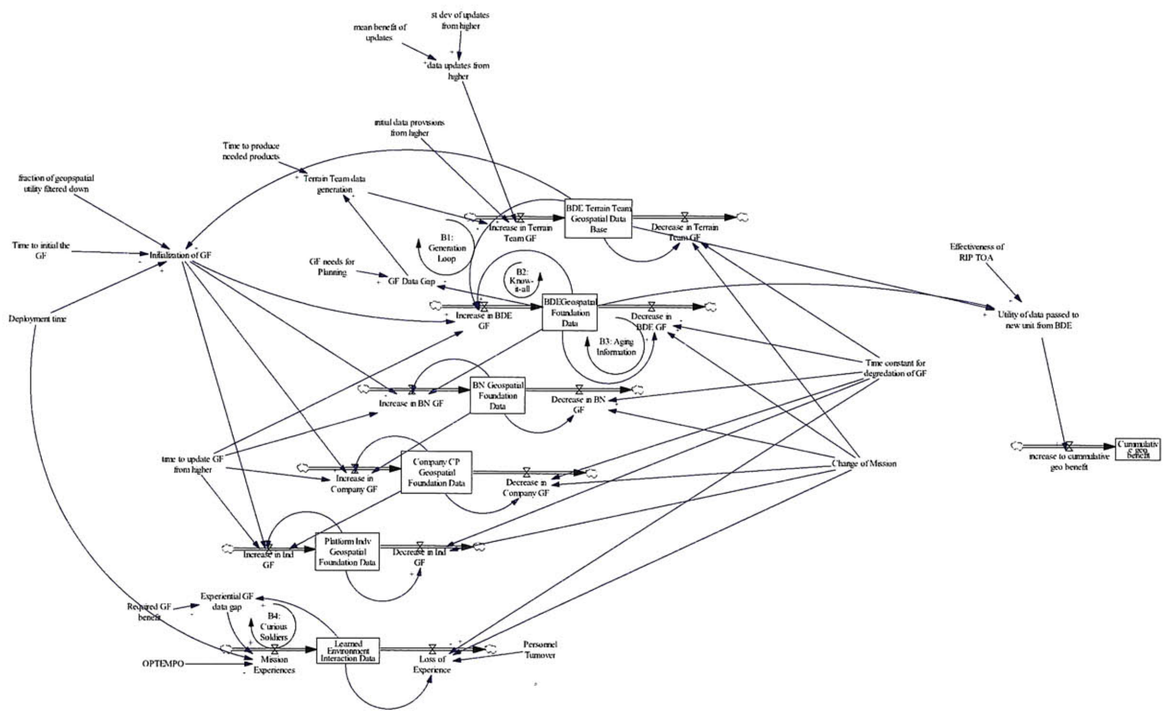


Figure 3-23: Current State AGE Model (Baseline)

3.6.6 Current AGE Experimentation with Geospatial Sensors

In 2004 the Topographic Engineering Center, now the Army Geospatial Center, fielded an experimental geospatial sensor system in order to increase the geospatial information capability of units deployed in Iraq and Afghanistan. The sensor system produces high resolution imagery over a commander's area of interest contributing to intelligence, surveillance and reconnaissance (ISR) and also to create detailed mapping of the battlespace. It is the high resolution imagery and elevation data mapping that was novel to the force, and provided an information advantage in tactical decision making for those that had access to the information. (Richards, "BuckEye" Fact Sheet: An Airborn High Resolution Digitial Imaging System 2006)

The system operates on several different airborne platforms, it is platform independent and it weighs approximately 30 pounds. The geospatial sensor can operate at a variety of altitudes, based upon the desired image resolution and image swath width. A variety of configuration options can meet each tactical application. The system is comprised of a digital camera to take near nadir pictures of an area, gyroscopes to measure the roll, pitch and yaw of the aircraft, an accelerometer, an encased processor and data storage system and a laptop used to control the sensor and monitor the collection while in flight.

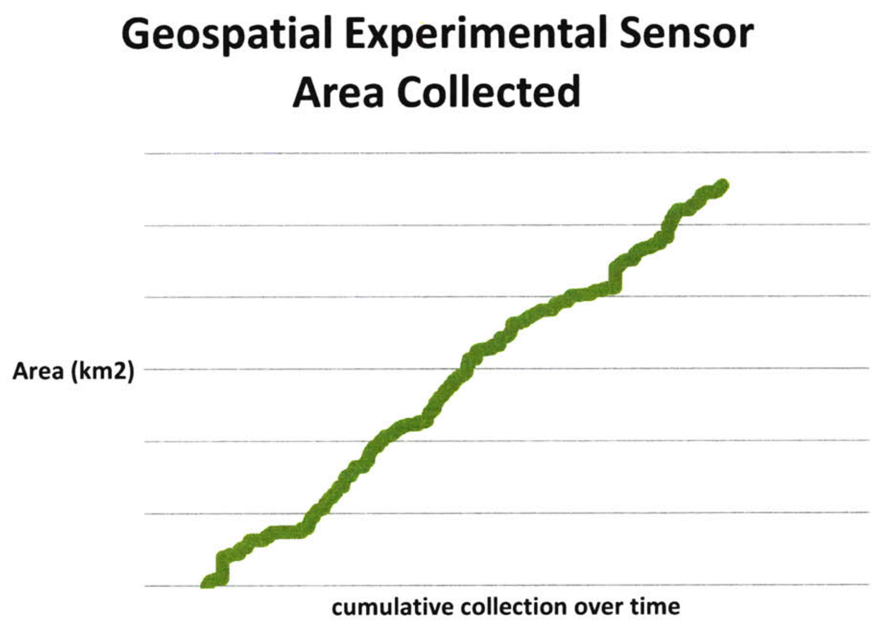


Figure 3-24: Geospatial Experimental Sensor Area Collected

The experimental sensor collects areas that have been prioritized by the units operating within that region. The speed of collection varies based upon weather conditions and system maintenance. As shown in Figure 3-24, the system has continuously collected data since it began operations in 2005.

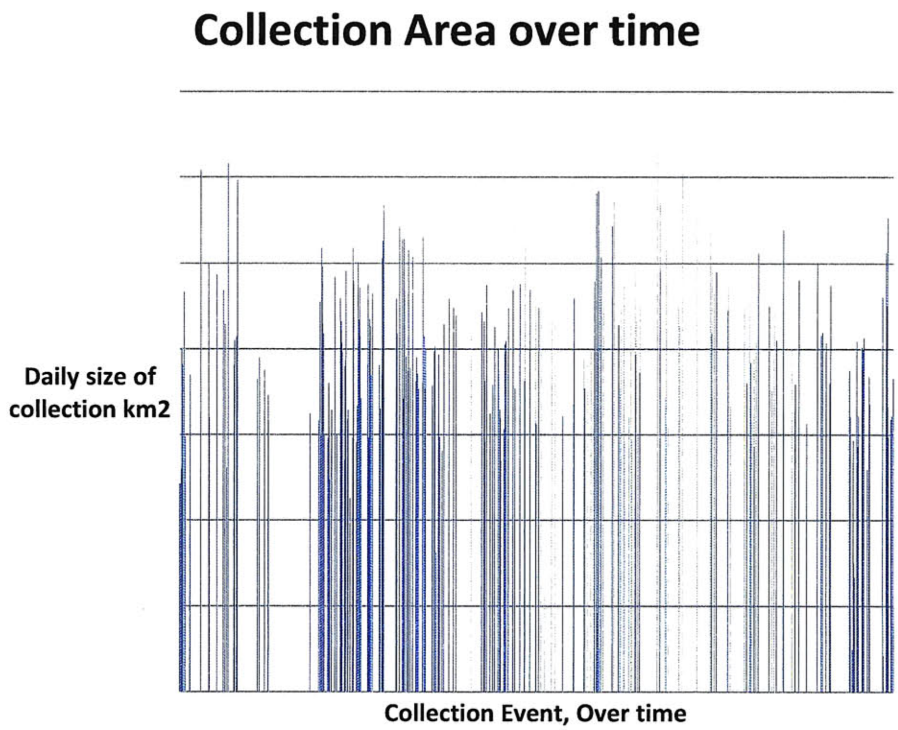


Figure 3-25: Relative Size of Areas of Collection for Experimental Geospatial Sensor

The size of the area collected is highly variable based on many factors. The size of the area of interest impacts how much data is collected. Also, the distance from the Forward Operating Base housing the system to the targeted area impacts the size of the collection. The longer the taxis time, the less collection will be possible. As is apparent from Figure 3-25, the size of the area is collected relatively random from zero up to the maximum collection size, with some central tendency around one half of the maximum size of collection. The data has been sanitized of

A final analysis of the experimental geospatial sensor system's performance is a Monte Carlo simulation. The simulation examines the collection records looking at the conditional age of each collection. Given that the area had already been collected at least one time, what was the age of the most recent data collection over that location? The simulation was conducted with Crystal Ball ® software drawing from a uniform distribution for the longitude and latitude of a location in the country for each of the iterations. One million iterations were conducted at each six month time step to insure that full coverage of the country was well achieved. Figure 3-26 shows the resulting age of the collections. It is apparent that the sensor system did not reach a steady state condition, where the locations of desired new collections could be filled as fast as the old collections aged. The carrying capacity of the sensor system could not support the required demand.

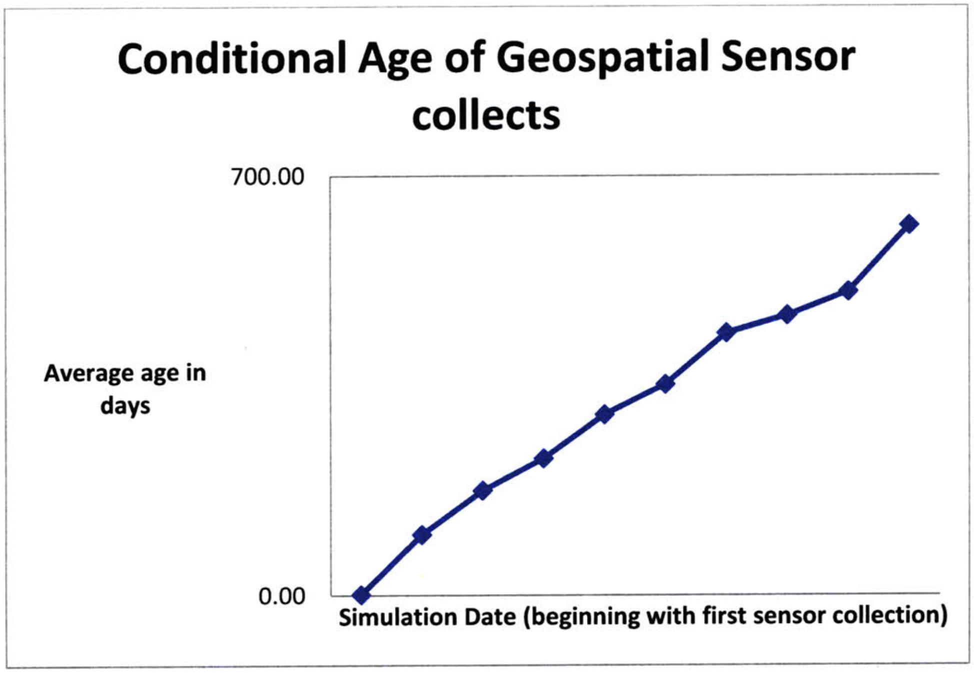


Figure 3-26: Monte Carlo Simulation of Experimental Geospatial Sensor Collections

3.7 Current State Summary

The "as is" architecture provides a solid foundation for enterprise architecting work and a starting point for the future state analysis. A value-creation framework combined with holistic enterprise architecting views is extraordinarily helpful to enable a more complete understanding of the "as is" AGE. Survey and interview feedback from various stakeholders is a productive method of value identification, which could be expanded and continued. Finally the use of simulation to quantitatively model a portion of the enterprise increases the accuracy of evaluation of changes to the enterprise. System dynamics is a helpful modeling tool in this regard, and the AGE boundary model could be expanded to include other parts of the enterprise.

4 Analysis of Army Geospatial Future Architecture

In order to define candidate future state architectures, the enterprise architect must establish a future state vision with associated behaviors, structures and performance metrics. Each of the views of the enterprise must be considered, as well as view interactions. The candidate architectures should be conveyed with clear models and description to allow for discussion, elaboration, and evaluation. The stakeholder value attributes meet the enterprise design variables determining the greatest opportunity for improvement. A value driven design approach drives the candidate generation from attribute to design variable, not the other way around.

There are many possible selection criteria such as cost benefit analysis, "-ilities" and options. However, for this analysis a very simple linear weighted sum of five attributes are used to derive utility. There are also many ways to evaluate each of the candidate future architectures against each other, such as Pugh matrices, trade off analysis, executable models (deterministic and probabilistic) which can help to inform the decision maker. The selection criteria are based upon the values of the enterprise leadership. Similarly, the method of comparison, and the visualization of that comparison outcome should take the decision makers into consideration. The best analysis is meaningless unless it can be effectively conveyed to the architectural decision makers and leadership at multiple levels of the enterprise. "Buy in" to the proposed new architecture for the enterprise must be achieved at all levels of the enterprise, and the selection process should support this persuasion effort. Selection criteria are chosen with as broad a time horizon as the enterprise requires or which is possible with given information. Also the possible extreme environmental and internal conditions of the enterprise are considered.

Finally, the future state vision and architecture must be approved by enterprise leadership so the architect should define a clear transformation plan. The planning of the transformation effort should place initiative and activities in a timeline which synchronizes the interfaces of the views of the enterprise within the most likely future environmental conditions.

4.1 Value Driven Design

"Value-focused thinking involves starting at the best and working to make it a reality. Alternative-focused thinking is starting with what is readily available and taking the best of the lot." (Keeney 1992) How does one develop enterprise future state alternatives? Historically, decision making endeavors have sought to identify alternatives for comparison and then selection. Given a complex system, the outcomes from implementing a transition plan to achieve some future state are difficult to predict. Sophisticated modeling may shed some light in the area of which design variables or "knobs" might work to achieve the desired future state of the enterprise, which would then achieve the desired value for the decision maker. But in many cases there is more than one "decision maker" stakeholder within a complex enterprise which may have multiple and differing attributes and value definitions. Within such an enterprise, a value driven design approach for the enterprise architecture may prove helpful. A value centric approach focuses on the attributes of the stakeholders, and how design variables support these attributes before beginning to consider decision alternatives. Keeney states it this way "focusing on the values that should be guiding the decision situation makes the search for new alternatives a creative and productive exercise.

It removes the anchor on narrowly defined alternatives and allows clear progress toward 'solving' the problem." (Keeney 1992)

There are two separate decision processes that need to be considered in the context of the Army Geospatial Enterprise. The first is the decision making of the AGE leadership which creates the conditions for value creation and delivery to all of the AGE stakeholders. The second decision process of interest is how the tactical decision maker uses geospatial information to effectively conduct operations with good understanding of the terrain. This decision process only considers one of the many stakeholders of the AGE, though the tactical decision maker is the primary beneficiary. The goal of this research is to better inform the decision process of the AGE leadership through better understanding of the impacts of the AGE on the tactical decision making process at the brigade level and below.

By modeling the AGE boundary and the tactical decision maker, insight is gained into how the architecture of the Army's geospatial enterprise can increase the value created at this important boundary. By examining the design variables, or architectural changes that impact value, future state alternatives can then be developed and compared.

Outside the scope of this research, additional stakeholders need to be evaluated, in additional to the tactical decision maker. For example, the effects of future state architectural changes upon Army information networks or National Level data producing bodies such as the National Geospatial-Intelligence Agency are critical to value creation across the entire enterprise. The approach shown here focuses on just one boundary of the AGE, but it could also focus on other boundaries and stakeholders interactions, producing a fuller understanding of the implications of the future state.

"Insights about a decision, not definitive choices about what to do, are the key products of focused thinking and analysis. Decision analysis provides answers for the model you have built of your decision problem. It does not provide answers for your decision problem. The model is and should be simpler than your real problem, yet complex enough that you cannot clearly think through it with unaided intuition. The analysis helps you think through that problem and provides insights from the answers to the model. You must then take these insights and consider their relevance and strength in influencing your thinking and the choices that you should make regarding the decision you face." (Keeney 2004)

The approach begins with the stakeholder attributes as defined in chapter three, and then develops the design variables that have the greatest impact on the beneficial attributes. These design variables represent the future state alternatives for the enterprise architecture.

4.2 Identification of Future States of Interest

In order to evaluate the future state alternatives, the utility of each alternative, as well as a relative cost of implementation must be derived. The fidelity of the model of the enterprise requires several simplifications and assumptions. The following discussions outline how the utility and the cost of each simulation are obtained.

4.2.1 Utility Function

The utility of geospatial information to the warfighter is the degree to which the beneficial attributes are met. Table 4-1 describes the broad attribute levels for both the mission and programmatic areas. The warfighter is concerned primarily with the mission areas. Though it is not ideal to aggregate utilities during the analysis, in order to simplify the model, an aggregation of all of the mission attributes listed below are calculated together for each level of the force structure, from individual Soldier to brigade level. The cumulative geospatial benefit uses another simplifying concept of utility. It is a linear weighted sum of all levels of geospatial foundation layer benefits. Each layer of the brigade has equal weight, 20% contribution to the total cumulative utility. Also, the benefit from the geospatial foundation layer is equally weighted each day over the length of the deployment. This simplification allows aggregation of the utility of the geospatial foundation layer across the entire brigade, which is the AGE enterprise boundary, or point of enterprise value delivery. It is quite apparent, based on the enterprise stakeholder analysis of chapter three, that this is certainly not the only point of enterprise value delivery, but for purposes of this model, it represents the values of the enterprise leadership. If value is not delivered at the brigade level and below, the enterprise will fail. This is a necessary but not sufficient condition for enterprise success. If value is delivered at the brigade, then understanding the rest of the value delivery among the other stakeholders, with proper value delivery and exchange, will be necessary for success.

4.2.2 Cost Model

The ability to measure the resource requirements of future state alternatives is critical to a proper evaluation of the future state candidate architectures. The programmatic attributes listed below define the resource cost drivers for the enterprise. This research does not attempt to elicit preferences from all stakeholders and enterprise decision makers in reference to their cost utilities. The approach taken here is to develop relative costs between the future state alternatives. This is accomplished through a very simplified cost model. The cost of each alternative is referenced to zero at the baseline, in other words, to make no change to the enterprise would cost nothing. Next, an arbitrary unit cost is assigned to an 86% increase in utility from the baseline enterprise model in the current baseline environmental conditions. This number was chosen because it represents the ESS future state alternative at its highest possible value, equivalent to 100% of effort expended in that area. Each of the costs of the other future state alternatives is referenced to this same cost baseline in order to not bias the model arbitrary toward one of the future state alternatives. This cost model captures approximate relative lifecycle costs of the different future state alternatives. The greatest cost drivers are the material procurement costs and the personnel lifecycle costs for manning and training. These are roughly represented in the model. Other programmatic attributes listed in Table 2-1 are not assessed, such as the value of faster implementation to change the enterprise and the improvement of technological development and reuse.

Table 4-1: Value Space Attributes

	Attribute Name	units	Range (U=0 to U=1)
Mission	[MAX] spatial resolution	m	1 -- > .01
	[MAX] completeness (covered area, fully attributed)	% AO	50 -- > 100
	[MIN] age of data (currency)	days	500 --> .1
	[MAX] "reach" of geospatial foundation data	% of Soldiers	1 -- > 100
	[MAX] synchronization of warfighting functions	% total systems	1 -- > 100
	[MAX] accessabliliity (connectivity, ease of interface)	% of issue occurance	50 -- > 0
	[MIN] classification level	Level	TS (SCI)+ --> Unclassified
Programmatics	[MIN] Time for changes to impact the enterprise	months	48 -- > 1
	[MIN] System development costs (one time investments)	$M	unknown
	[MIN] Recurring costs over lifecycle	$M	unknown
	[MAX] stability of enterprise interfaces	years	1 -- > 10
	[MAX] reuse of geospatial development effort	% total systems	1 -- > 100

4.3 Defining the Design Vector

The total design space identified is relatively large. Each of the 14 design variables can take on at least two values, some of which are continuous variables. Table 2-2 outlines the design variables identified, though not all of these design variables will be explored in their entirety within this study. There are many other design variables which could be investigated further for a more complete study of the enterprise and the possible future states available to leadership. The design variables chosen for discussion and detailed modeling, reflect a summary of the current thinking within the community on ways to improve the enterprise.

Table 4-2: Design Variables for AGE based on DOTMLPF Categories

	Variable Category	Design Variable Name
Design Variables	- Doctrine: the way we fight, e.g., emphasizing maneuver warfare combined air-ground campaigns	Geospatial Standards (degree of synchronization and enforcement)
		Method to force GF update based on information from operations
		Senior Geospatial Officers (Synch Geo)
	- Organization: how we organize to fight; divisions, air wings, Marine-Air Ground Task Forces (MAGTFs), etc.	Addition of 215D to all BDEs
		Geospatial Synchronization Personnel at each level
	- Training: how we prepare to fight tactically; basic training to advanced individual training, various types of unit training, joint exercises, etc.	Level of geospatial capability with 21Y/215D
		Geospatial training for non-geospatial MOSs
	- Materiel: all the "stuff" necessary to equip our forces, that is, weapons, spares, etc. so they can do operate effectively	C4ISR systems capability for geo info exchange
		All WFFs programs aligned with geospatial information CONOPS
		Geospatial sensor system
	- Leadership and education: how we prepare our leaders to lead the fight from squad leader to 4-star general/admiral; professional development	Geospatially aware senior PMs / Army leaders
		Tactical geospatial consumers aware of geospatial capability
	- Personnel: availability of qualified people for peacetime, wartime, and various contingency operations	All key positions (mil/civ) filled in geospatial community
	- Facilities: real property; installations and industrial facilities	Geospatial BDE HQs co-located with AGC or training base

The design variables are the "knobs" that system architects possess to impact the desired attributes of the enterprise stakeholders. Again, the list is not exhaustive, but is representative of the types of adjustments that can be made within the enterprise. The DOTMLPF categorization organizes the possible design variables into groups of similar enterprise architecture adjustments.

Table 4-3: Design Value Matrix with Design Variable Impacts

Design Value Matrix

			Attributes												
			Mission							Programmatics					
	Design Variable Name	Definition Range	[MAX] spatial resolution	[MAX] completeness (covered area, fully attributed)	[MIN] age of data (currency)	[MAX] "reach" of geospatial foundation data	[MAX] synchronization of warfighting functions	[MAX] accessibility (connectivity, ease of interface)	[MIN] classification level	[MIN] Time for changes to impact the enterprise	[MIN] System development costs (one time investments	[MIN] Recurring costs over lifecycle	[MAX] stability of enterprise interfaces	[MAX] reuse of geospatial development effort	Total Impact
Design Variables	Geospatial Standards (degree of synchronization and enforcement)	No standard compliance -> Uses commercial stds	0	3	0	3	9	3	0	1	3	1	9	3	35
	Method to force GF update based on information from operations	Degree of ESS implementation in doctrine 0 -> 100	1	3	9	9	9	3	3	9	3	3	3	3	58
	Senior Geospatial Officers (Synch Geo)	No Change; ID Sen Geos ->Fully implemented	1	1	3	9	9	9	1	9	3	3	9	3	60
	Addition of 215D to all BDEs	No 215D at BDEs -> 215D at all BDEs	0	1	0	1	1	1	0	3	1	1	3	0	12
	Geospatial Synchronization Personnel at each level	No Synch Geo -> Synch Geo each level to CO level	1	1	3	9	9	9	1	3	1	1	3	1	42
	Level of geospatial capability with 21Y/215D	No change to trng. -> masters cert. program	1	1	0	1	1	1	0	3	1	1	3	0	13
	Geospatial training for non-geospatial MOSs	No geospatial training -> all MOS detailed trng prg	3	1	3	3	3	3	0	3	1	3	3	3	29
	C4ISR systems capability for geo info exchange	No geo exchange device -> fielded to each Soldier	3	3	1	9	9	9	0	3	9	3	3	3	55
	All WFFs programs aligned with geospatial information CONOPS	No WWF alignment -> all systems geo enabled	1	3	0	3	9	3	0	3	1	1	3	3	30
	Geospatial sensor system	No geospatial sensor -> Geo Sensor at BDE level	9	9	9	0	1	0	3	3	9	9	3	9	64
	Geospatially aware senior PMs / Army leaders	No additional training -> geo trng at all PME levels	0	0	0	3	3	1	3	3	1	1	9	3	27
	Tactical geospatial consumers aware of geospatial capability	No geo ldr update -> integrated digital geo trng	1	3	1	9	3	3	0	1	1	1	3	3	29
	All key positions (mil/civ) filled in geospatial community	75% positions filled -> 100% positions filled	0	1	0	1	0	1	0	1	1	1	1	1	8
	Geospatial BDE HQs co-located with AGC or training base	No Geo BDE -> co-located geo BDE, AGC	0	0	3	3	1	3	1		0	3	9	9	32

A qualitative analysis of the contribution each of the above design variables to the stakeholders' attributes reveals the areas that the architect should focus on first. The highest impact design variables have the potential to yield the highest returns to the enterprise; therefore these areas deserve the most consideration and most initial analysis. Each of the design variables is rated on a scale of zero to nine to have the greatest beneficial impact on the attributives, Table 4-3. The highlighted items are the three highest scoring impact variables; these are the variables chosen for modeling as the basis for architectural futures state candidates.

In order to properly compare each of the above design variables, the cost of each variable must be known. Since the costs of changes to the architecture were difficult to obtain rigorously from the survey data and interviews, relative costs tied to a baseline cost to benefit point is used. The baseline simulation of the Every Soldier as Sensor architecture yielded a benefit increase of 83%. This increase is assigned a cost of one, or 100% relative cost. Each of the other architectural approaches are then scaled to this cost increase of 100% at 83% increase in benefit.

4.4 Modeling Select Future State Alternatives

There are three areas which this research will model in more detail. Ideally all possible future state possibilities would be modeled to determine possible interactions that might add value. Due to the size of the design space, three areas for further investigation have been chosen. First, within the doctrine category, the policy and process that enables the Every Soldier as Sensor (ES2) concept could be used to update the geospatial foundation data of the brigade. Second, an organizational change, assigning a senior geospatial officer to each echelon to control the geospatial foundation layer, enforce standards, and promote interoperability would focus on increasing information flows. Finally, a material solution, adding a geospatial sensor capability to the brigade force package would provide an organic geospatial source to the front end of the value stream. Each of these alternatives is addressed below with modeling discussion and results.

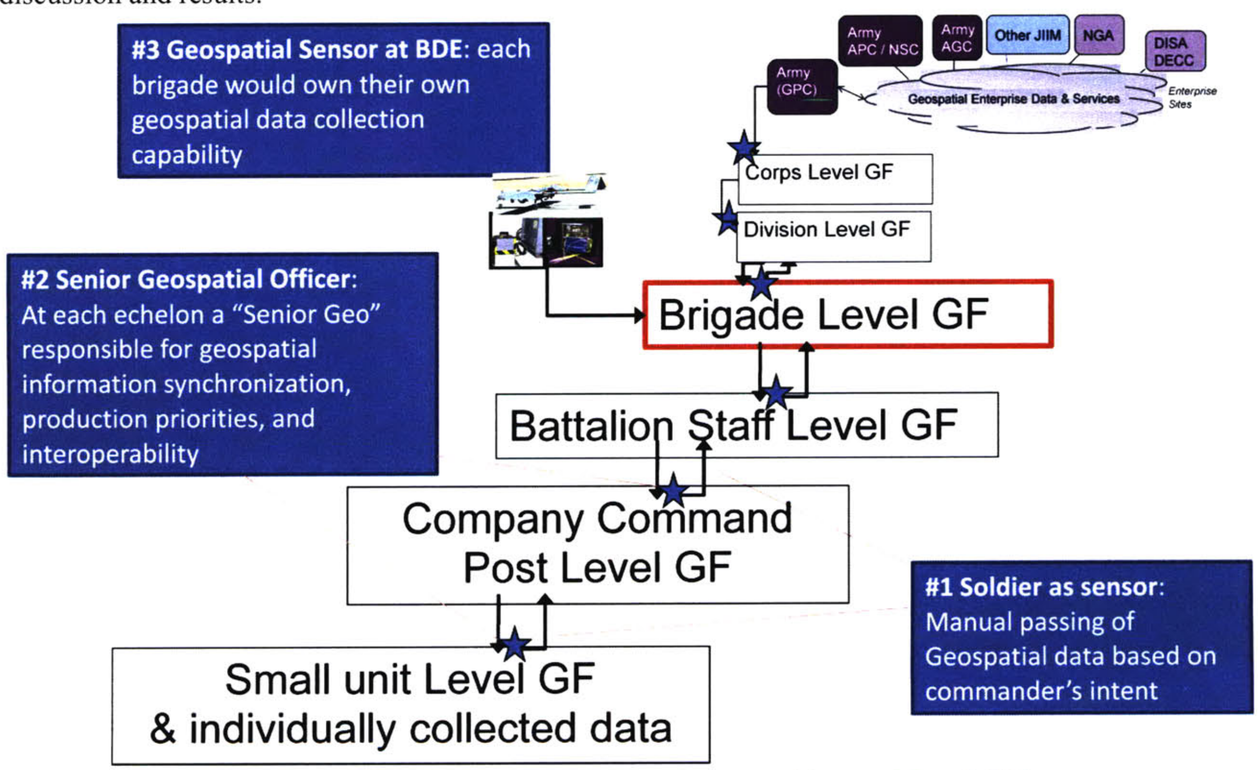


Figure 4-1: Three Army Geospatial Enterprise Architectural Possibilities

Each of the future state alternatives is linked to one or more design variables. Table 4-4 shows which design variables are coupled with each of the future state alternatives. The more design variables that a candidate architecture is coupled with, the greater the need for synchronization during implementation. The primary design variable and the associated design parameters are highlighted in Table 4-4 below.

Table 4-4: Relationship of Future State Architectures and Design Variables

Future State Alernatives Name
1. Every Soldier as Sensor
2. Synch Geo
3. Geospatial Sensor

Design Variable Name	Linked to Future State
Geospatial Standards (degree of synchronization and enforcement)	1
Method to force GF update based on information from operations	1
Senior Geospatial Officers (Synch Geo)	2
Addition of 215D to all BDEs	2
Geospatial Synchronization Personnel at each level	2
Level of geospatial capability with 21Y/215D	2
Geospatial training for non-geospatial MOSs	1, 2
C4ISR systems capability for geo info exchange	1
All WFFs programs aligned with geospatial information CONOPS	1
Geospatial sensor system	3
Geospatially aware senior PMs / Army leaders	1
Tactical geospatial consumers aware of geospatial capability	1, 2
All key positions (mil/civ) filled in geospatial community	2
Geospatial BDE HQs co-located with AGC or training base	-

4.4.1 Every Soldier as Sensor: Modeling the Bottom Up Data Flow

Why should the AGE capture information about the battlespace from the experiences of the Soldiers operating in the battlespace? The knowledge and experiences that each Soldier has with the terrain are a fantastic wealth of information that is hardly touched in the AGE current state architecture. In most current operations, Soldiers operate over the same terrain for months at a time, accumulating significant knowledge of the terrain.

"Clearly, Soldiers are exposed to information that would be of significant value if collected, processed and integrated into a Common Operating Picture; hence, the concept of 'Every Soldier is a Sensor.'" (Association of the United States Army 2004)

A survey response from a warrant officer that served in Iraq stated the frustration in this way. "There were no methods to capture geospatial data from various organic sources within the Corps unless I manually hunted for them and jammed them into my database. For instance the C5 guys [civil affairs team] had a list of hospitals on a spread sheet with some information that I needed to fill in holes in my urban database. If I had not gone to them and discovered this spread sheet I would never have known about it. Many such examples happened throughout the operation." (Geospatial Community Survey 2009) The ESS candidate future state architecture seeks to enable the brigade to capture the experiences of Soldiers conducting operations, and place that information into the geospatial foundation layer.

4.4.1.1 Adaptations to the Architecture

There are two general architectural approaches to capturing the knowledge generated by conducting operations into the geospatial foundation layer. Again, the discussion at hand is focused on the geospatial foundation layer and not other warfighting function information layers that are impacted by the Every Solider as Sensor. Capturing this information all of the way down to the geospatial foundation layer, which is the basis of the common operating picture, is central to the foundation of the Every Soldier as Sensor premise. These experiences could be captured into the information domain directly through some embedded sensor system with the Soldier or they could be captured indirectly through the cognitive domain of the Soldiers conducting the operations.

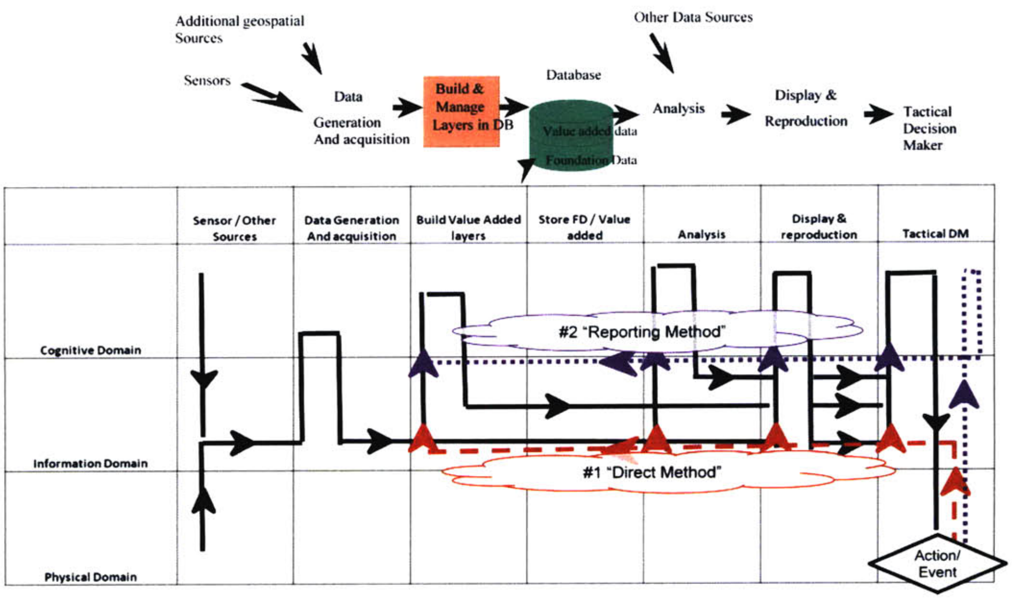


Figure 4-2: Geospatial Information Architectural Approaches to Every Soldier as Sensor

Updating the geospatial foundation layer directly occurs when geospatial capable sensors accompany Soldiers on operations and then that data, in part or in totality, becomes part of the geospatial foundation layer. This could be done with digital cameras that have geospatial location and orientation capability. It can also be done by characterizing routes with a combination of sensors and the blue force tracking location data streams. Or perhaps in a more sophisticated future setting, a vision aided navigation system, worn by individual Soldiers, could be leveraged to robustly update the geospatial foundation in real time. The benefit to this approach is that it has a direct link to the level of the information domain closest to the geospatial foundation layer. The method could potentially include a very large data set of information from the operation. The down side to this method is that since it does not pass through any cognitive filters, the pertinence and importance of the data would be unknown. Also, the ratio of beneficial information to the bandwidth of the total data set might be relatively low.

The second approach to capturing knowledge from operations and placing this back into the geospatial foundation layer is to do so through the cognitive domain of the Soldiers conducting the operations. This occurs primarily by Soldiers creating text-based patrol reports following an operation.

They would report back on the commander's critical information requirements (CCIR). The information would most likely mirror the cognitive domain of the Soldiers, in a sense, a story telling the parts of the operation that the Soldier thought were important. Then for this text data to become part of the geospatial foundation layer, some geocoding effort would be required. This could be conducted by the operators themselves, in a sense a post processing of their initial reporting process. But more realistically this would be conducted by the intelligence section or terrain team closest to the mission. However, this might result in a plethora of reports that potentially would not be used to update the geospatial foundation layer due to a lack of manpower or available resources. The benefits of this process are that it uses the distributed processing power of the cognitive domain of the Soldiers closest to the direct sensing experience of the battlespace to determine what might truly be important to future operations from a geospatial perspective. The downside is that it might miss some important phenomenon on the battlespace that would be discounted as unimportant, but would have been valuable information for the geospatial foundation.

For purposes of this analysis, the direct approach is modeled. Geospatial information acquired through operations is transferred through an information link to the geospatial foundation layer to the brigade terrain team, brigade staff, battalion staff, company staff and down to the map system in each vehicle or carried by each individual. The first simulation of this capability within the enterprise looks at the enterprise benefit of 25% of geospatial information captured back into the foundation layer. Results are shown below in Figure 4-3.

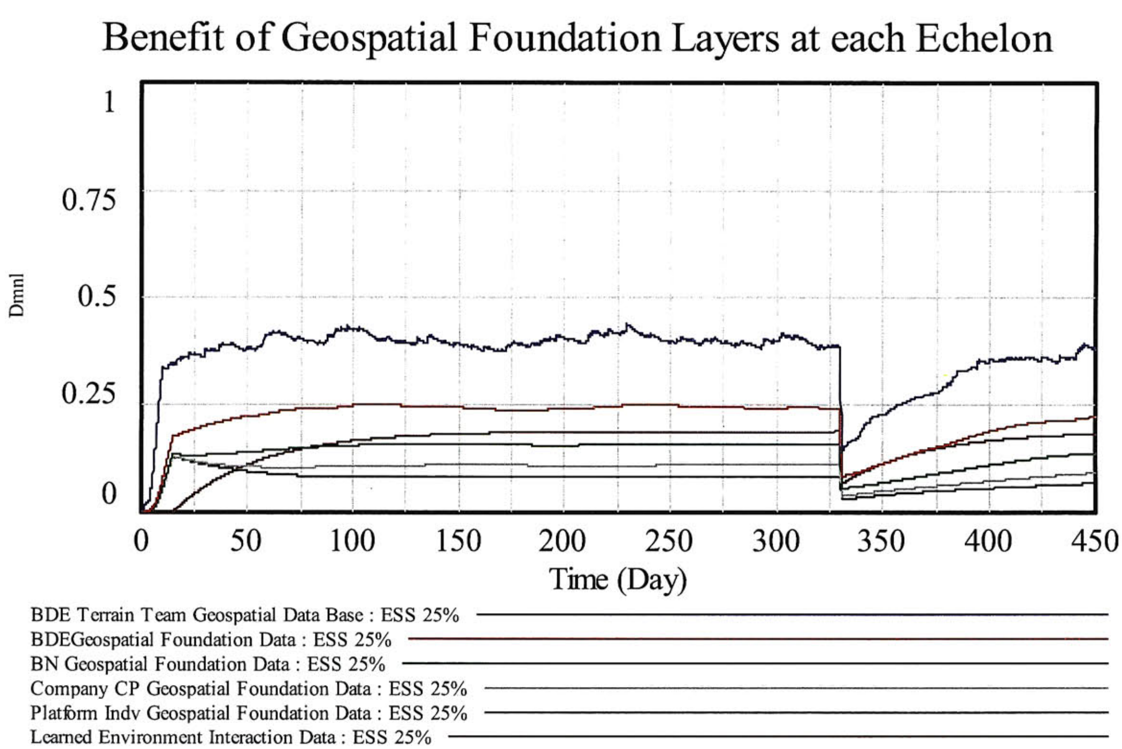


Figure 4-3: Every Soldier as Sensor 25% Effective Future State

The ESS future state represents the ability for each Soldier conducting missions within an Area of Operations to contribute the knowledge that they have gained about the terrain back into the geospatial foundation data. The first simulation assumes that 25% of all of the information that Soldiers obtain is available in the geospatial foundation layer at all echelons of the brigade. These increases in information utility at the higher levels have a synergistic, or knock on effect, to increase the utility of the generated geospatial foundation layer at the brigade terrain team level. There still is a "crossover" point where a Solider operating for an extended period in an area would have better geospatial foundation knowledge than the geospatial foundation layer of their map system. But the overall geospatial benefit, after the 450 days of operations with one change of mission at 330, is 21% greater than the baseline geospatial foundation layer with no update from ESS.

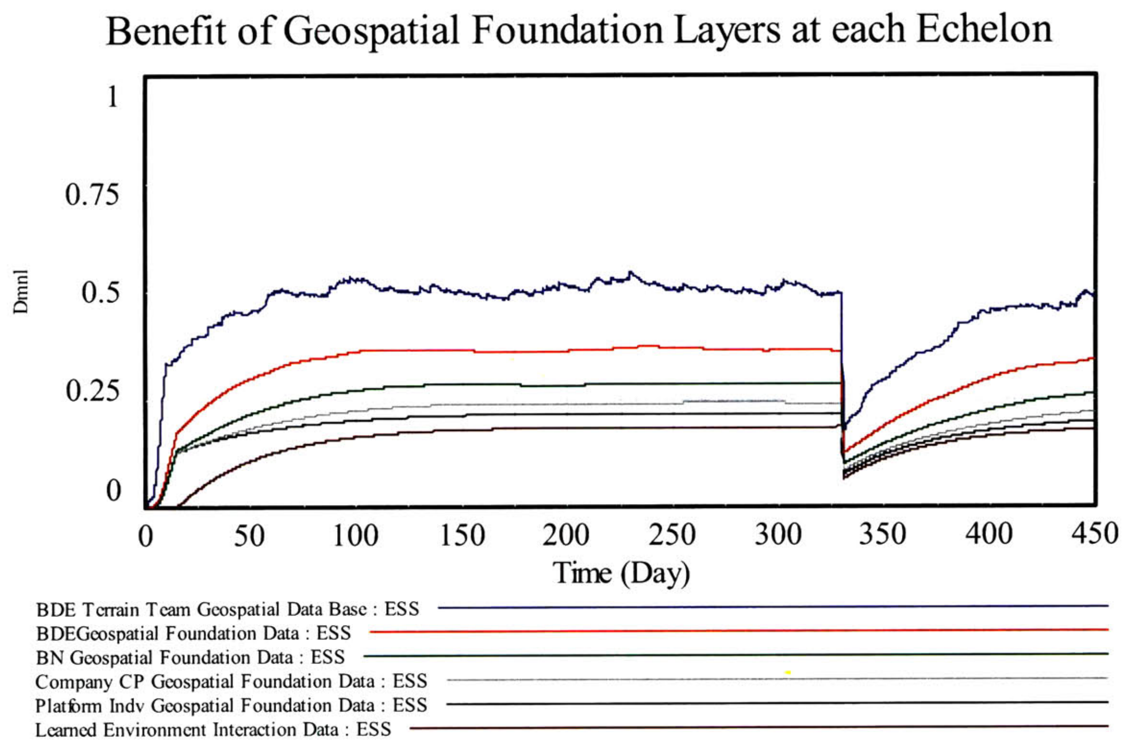


Figure 4-4: Every Soldier as Sensor 100% Effective Future State

Taking the ESS geospatial benefit to the extreme, the enterprise is modeled with 100% of terrain information experienced in operations included back into the geospatial foundation layer. Figure 4-4 shows the benefit of the geospatial foundation layer with a 100% inclusion of information from operations into the geospatial foundation layer. This time there is no "crossover" point where a Soldier would trust the information of their experience more than the information of their geospatial foundation layer, since all that they have learned about the terrain has been included in the foundation layer. This significantly increases the benefit of the geospatial foundation layer at each level in the brigade. The benefit increase from the baseline case is 86%.

This future state alternative has a physical limitation where only information obtained from operations is used to update the geospatial foundation layer. Therefore, the maximum level of the ESS model parameter is 100%. Even this level is extraordinarily optimistic, since it implies that the ESS capability enables all information of an operation to enter the information domain. Each staff member conducting planning for future missions in that area could say, "It is as if I am really on the mission myself." Even Hollywood is not able to capture the complete context of environmental factors equally well as "being on the ground" so it is doubtful that a fielded system would be able to achieve quite that level of reality in the information domain.

Because the foundation layer is updated at each level of the brigade echelon at the same time, the overall benefit from the ESS structure is linearly related to the total benefit of the geospatial foundation layer. Figure 4-5 shows the linear relationship, beginning at no investment in ESS and ending with a total investment yielding complete sharing of information back into the geospatial foundation layer.

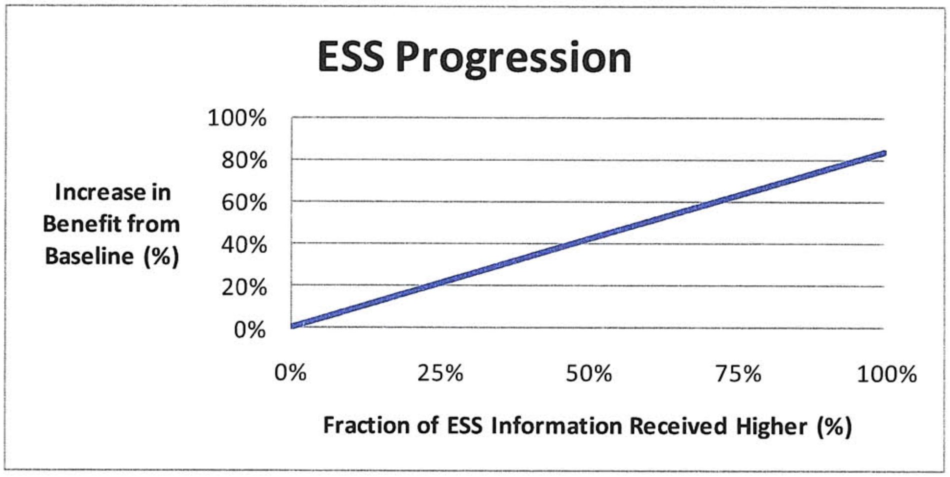


Figure 4-5: Progression of Benefit from the ESS Future State Alternative

4.4.2 Synch Geo - Senior Geospatial Officer, Synchronization at Each Echelon

A second future state enterprise architecture available to the AGE is to place a senior geospatial officer at each echelon in the Army. This individual would be the conduit for improved information exchange at each level. They would synchronize geospatial foundation activities along the entire value stream at their level, to include production, analysis, and dissemination of information. The goal of the "Synch Geo" would be to achieve a Common Operating Picture with the greatest benefit to all warfighting functions operating on the COP.

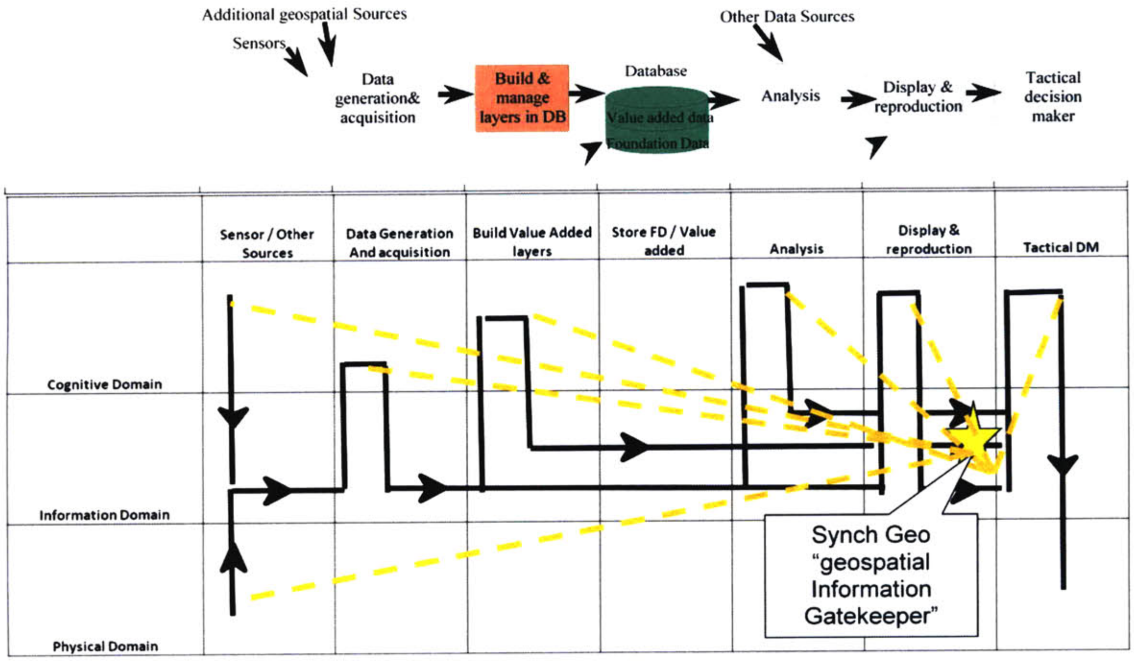


Figure 4-6: Geospatial Information Architectural Approach to Synch Geo

As the process, organizational and knowledge views (as discussed in section 3.4) of the enterprise change with the addition of the senior geospatial officer at all echelons of the brigade, there are several effects on the performance of the enterprise. First, the time it takes to synchronize the geospatial foundation layer among the different echelons decreases. The second effect is to increase the fraction of information included in the exchange. Less information is left at the higher levels, enabling greater utility of geospatial information at each level. The simulation of the 25% implementation of the synch geo future state architecture yields a 9% increase to the baseline. Figure 4-7 shows the benefit of the geospatial foundation layer at each level.

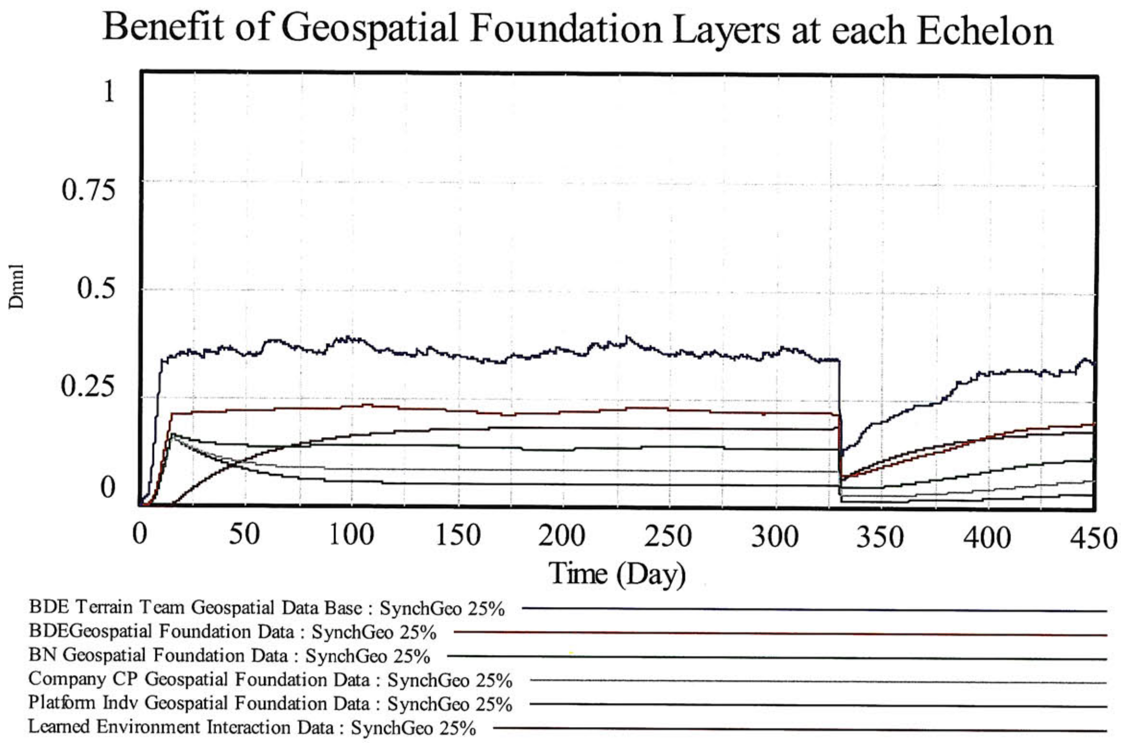


Figure 4-7: Synch Geo 25% Effective Future State

It is possible to increase the implementation of the synch geo future state. As a greater fraction of information is exchanged and the time it takes to propagate utility of foundation information around the battlefield decreases, the utility of each level more closely approaches the benefit of the total geospatial information of the brigade terrain team, or the highest geospatial benefit in the brigade. This future state requires systems capable of geospatial information processing and visualization at all levels, with Soldiers trained on how to understand and make decisions from the information. The effect of the architecture creates "mini" one person terrain teams at echelons lower than brigade. The capability of the terrain team is filtered down to all Soldiers by way of the synch geo individual at each unit. Figure 4-8 depicts the effect on the enterprise of the greater degree of synch geo implementation.

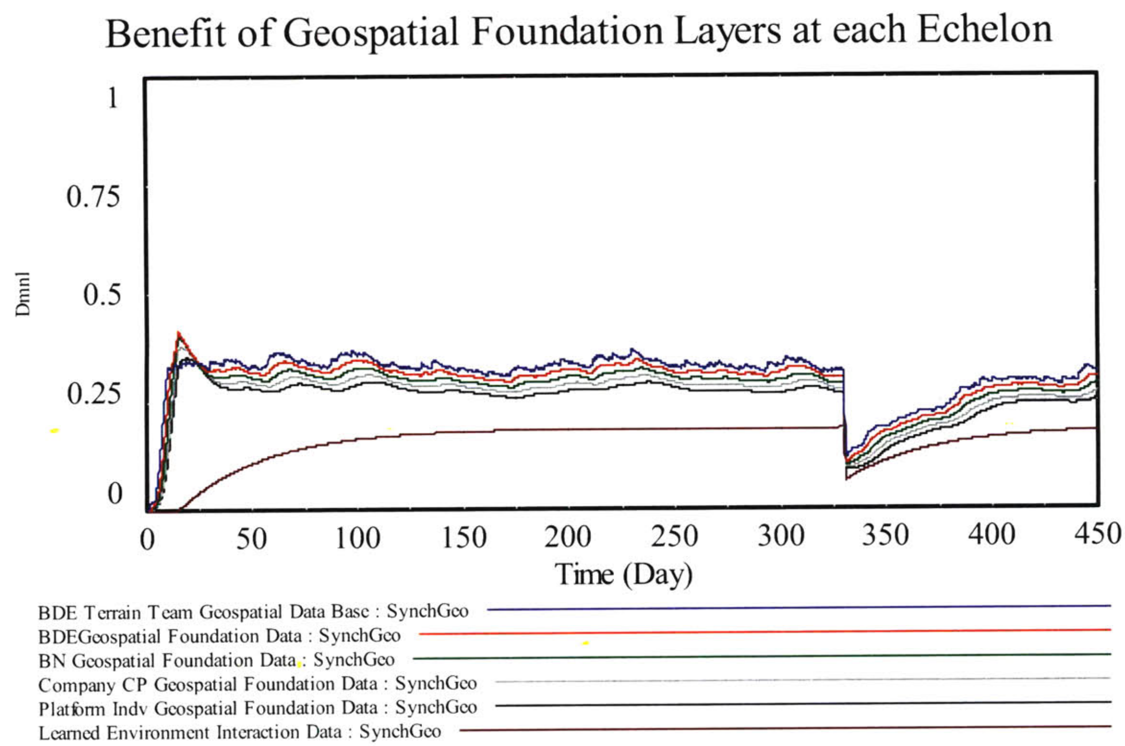


Figure 4-8: Synch Geo 100% Effective Future State

There are two synergistic, knock on effects to having information faster. First, the speed of synchronization allows better products to be produced at the brigade terrain team level which in turn makes even better information available more quickly at the lower levels of the brigade. At higher levels of synch geo effort and implementation, there are diminishing returns. Similar to the ESS alternative, there are physical limitations to the speed of geospatial foundation updating that are not overcome by organization or knowledge (the two primary views leveraged with this future state architecture) within the enterprise. Therefore, the benefit progression assumes an "s shape" growth behavior as shown in Figure 4-9.

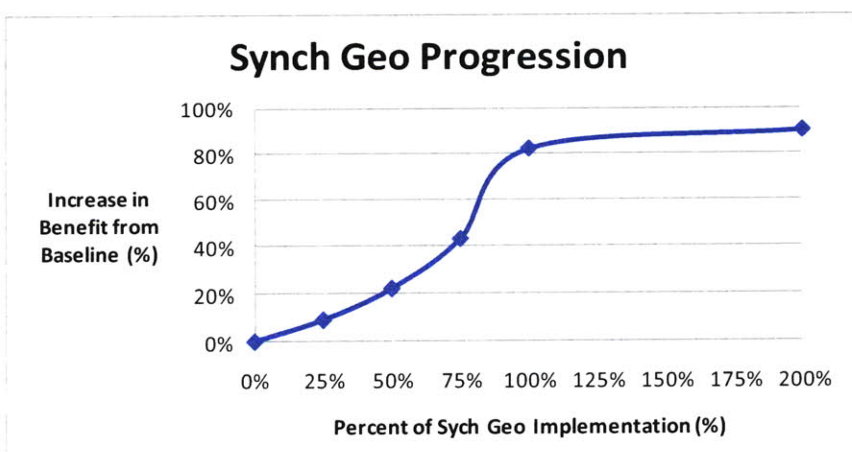


Figure 4-9: Progression of Benefit from the Synch Geo Future State Alternative

4.4.3 Geospatial Sensor - Addition of sensor system at the Brigade Level

The geospatial sensor future state alternative provides the brigade with the capability to obtain its own geospatial information, organically within the brigade. Of all the alternatives, the geospatial sensor future state has the least coupling of the design variables. It can be implemented as a material solution added to the authorizations of the brigade, with some additional training of a small number of system operators. Without other changes, such as doctrine or organization (enterprise interactions), the sensor system might go unused. The geospatial sensor candidate future state models the implementation of a sensor system only; the interactions will be addressed in the hybrid architecture performance in section 4.5.

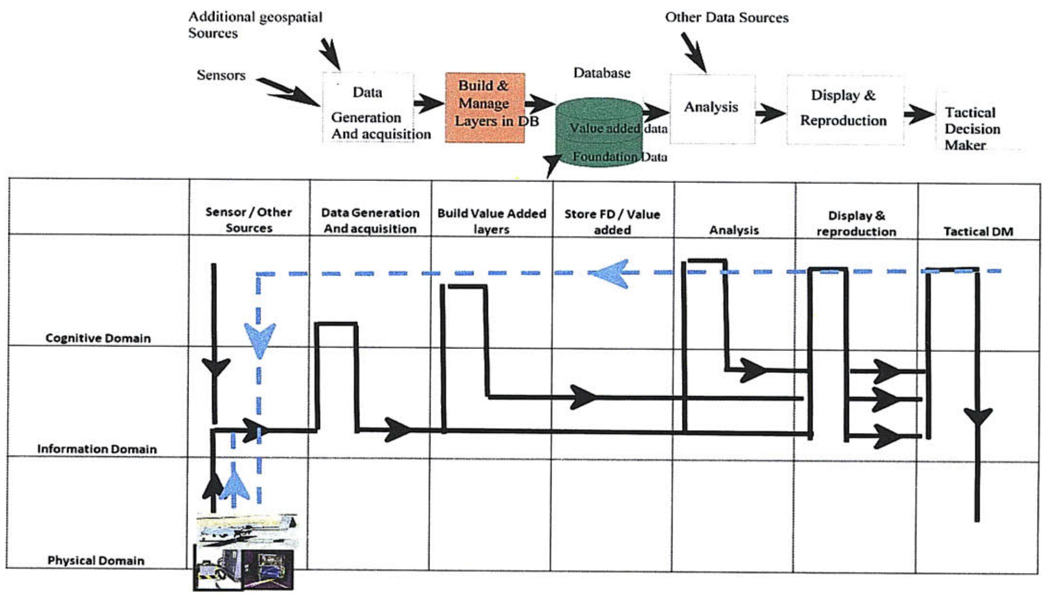


Figure 4-10: Geospatial Information Architectural Approach to the Geospatial Sensor

Similar to the synch geo future state alternative, the geospatial sensor alternative has relatively small returns at a low level of implementation. As higher quality geospatial foundation products are produced from the sensor system, greater utility enters the brigade terrain team and filters down through the brigade. This sensor system is subject to all of the same information time delays that the base case has, which decreases the ability of the system to impact the lower levels of the brigade.

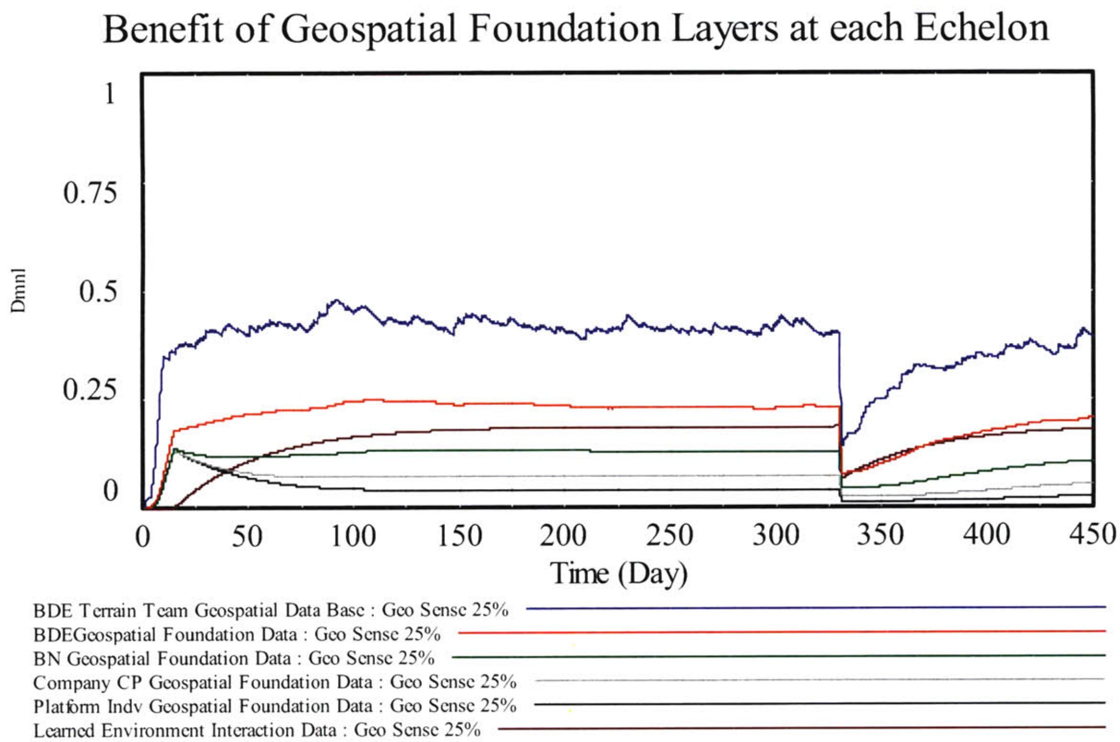


Figure 4-11: Geospatial Sensor System 25% Effective Future State

As the geospatial sensor system future state is implemented, there is a significant increase in the quality of the geospatial information entering the brigade during deployment. Instead of having to wait for a national level agency to produce a new product over the AO of interest to the brigade, this high resolution collection system can be tasked, collected and produced all within the brigade. Figure 4-12 shows the effect of 100% geospatial sensor implementation within the enterprise. The benefit of the geospatial foundation layer at the terrain team level increases significantly, but because time delays and inefficiencies of data transfer down to the lower levels continue to exist, there is a widening gap between the operating picture of the higher levels with the COP and the lower levels of the brigade. This would most likely have negative effects on the other warfighting functions. Figure 4-13

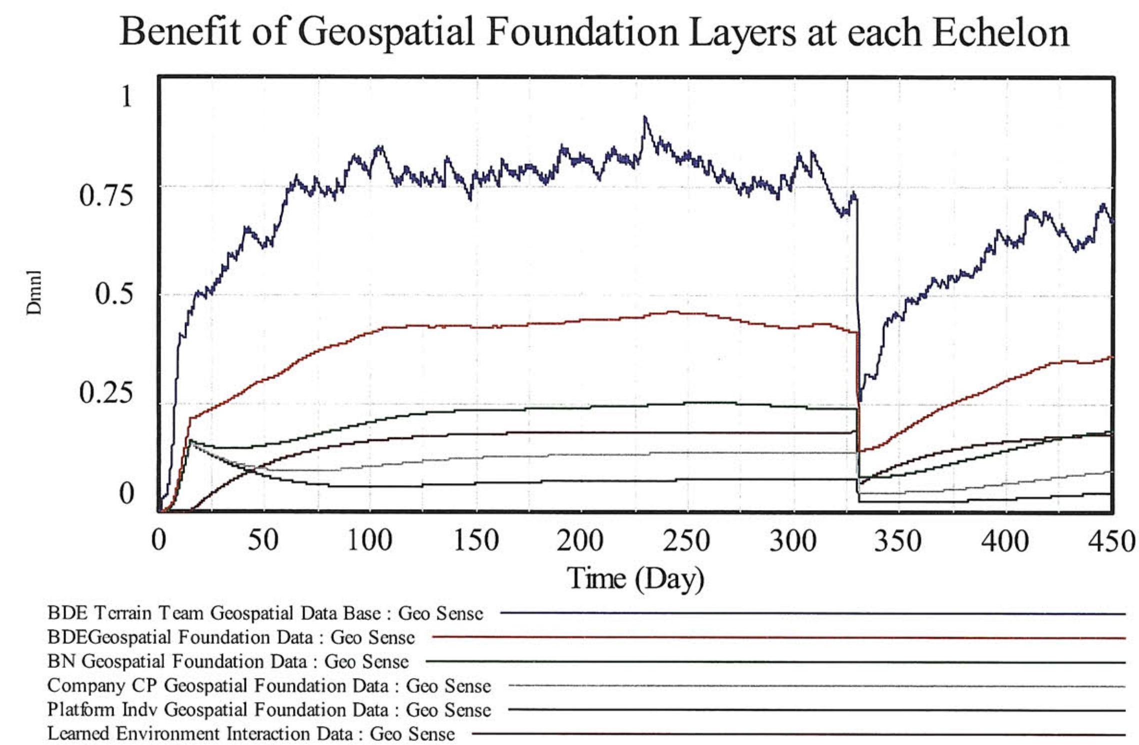


Figure 4-12: Geospatial Sensor System 100% Effective Future State

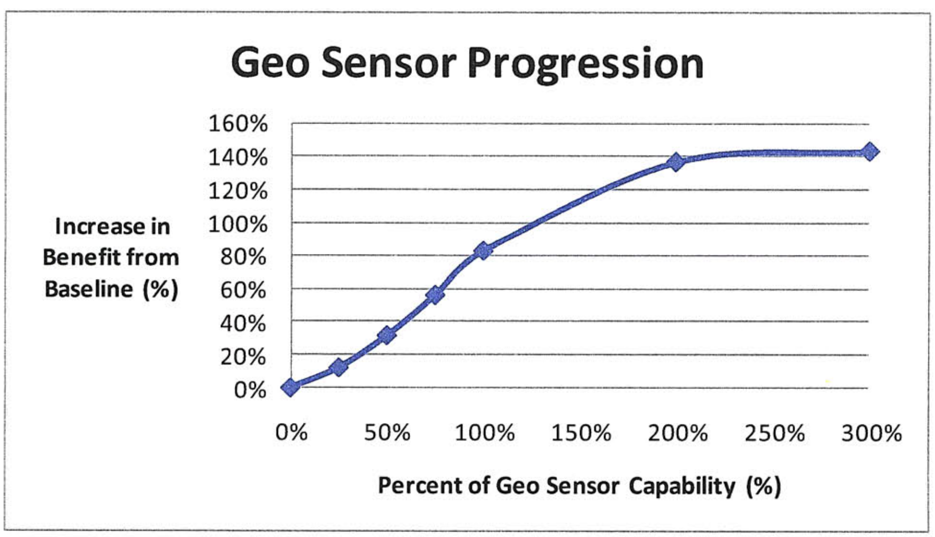


Figure 4-13: Progression of Benefit from the Geospatial Sensor Future State Alternative

4.5 Hybrid Future State Alternatives

The three candidate architectures listed above are not mutually exclusive in structure or behavior. The only constraint against implementing a hybrid architecture which includes aspects of two or three of the architecture approaches would be from a resource or funding shortfall. In fact, there are additional synergies or "knock on" effects that increase the value creation more than a linear sum of the benefit from two of the candidate future states.

There are four possible hybrid future state architectures given the three basic future state architectural approaches analyzed. Each of the four combinations is analyzed for performance comparison in Table 4-5.

Table 4-5: Hybrid Future State Architecture Comparison (Baseline Environment)

ESS& Synch Geo	Synch GEO& Geo Sen	Geo Sensor & ESS	All FS Together
0.44	0.60	0.45	0.73
158%	254%	165%	330%

The greatest benefit of the hybrid future state occurs if all three future state architectures are implemented simultaneously. If only two architectures are applied, the hybrid of the geospatial sensor and synch geo architectures has the best performance. The ESS future state alternative does not have the same level of synergistic effects as the combination of the other two architectural approaches because of the structure and reliance on information flow internal to the brigade. This internal focus blunts the total increase in benefit in the context of the baseline environmental conditions.

4.6 Epoch-Era Analysis: Dynamic Value within the Army Geospatial Enterprise

The Epoch-Era Analysis approach applies well to enterprises in addition to the more traditional use for system value robustness analysis (Ross and Rhodes 2008). An epoch is a period of time over which the expectations of the performance of the attributes desired by the stakeholder remain fixed, as well as the context within which the enterprise operates. Environmental factors such as technology, personnel, and resources available to the enterprise define the context of the epoch. An era is a series of epochs linked together over a longer period of time. This linkage defines the environment through the lifecycle of a system or enterprise. Researchers have used Epoch-Era Analysis across a wide array of methodological scopes and scales.

As discussed in section 2.5.6, the environment in which the AGE exists is constantly changing. It is impacted by upstream factors, such as changes to technology and policy, as well as downstream factors, such as the type of mission, the type of terrain, and the capabilities of the unit. Given the number of factors that impact the AGE performance, many epoch variables over a large number of possible future epochs could be analyzed. Two epoch variables defining four environmental conditions, the baseline and three additional future epochs above the baseline are analyzed. The two variables are frequency of change of mission and the rate of change of the terrain.

4.6.1 Baseline Epoch Analysis

The first variable is the time that a unit stays in the same physical area of operations. In the baseline, the brigade was assigned the same terrain for 330 days, concluded by a single relief in place by another brigade element. This is similar to many of the operations in Iraq and Afghanistan today. But it is quite possible to imagine a conflict that required moving the fight across new terrain much more quickly. This creates a much more difficult environment for geospatial value creation. Epoch A changes the frequency of change of mission from 330 days to 30 days. This means that the brigade would completely change the area of operations every 30 days, or approximately 10 times during a typical deployment cycle. Since this variable is an aggregation across the entire brigade, the rate of change could be faster or slower for the subordinate units and the model would simulate approximate results on the brigade's geospatial performance.

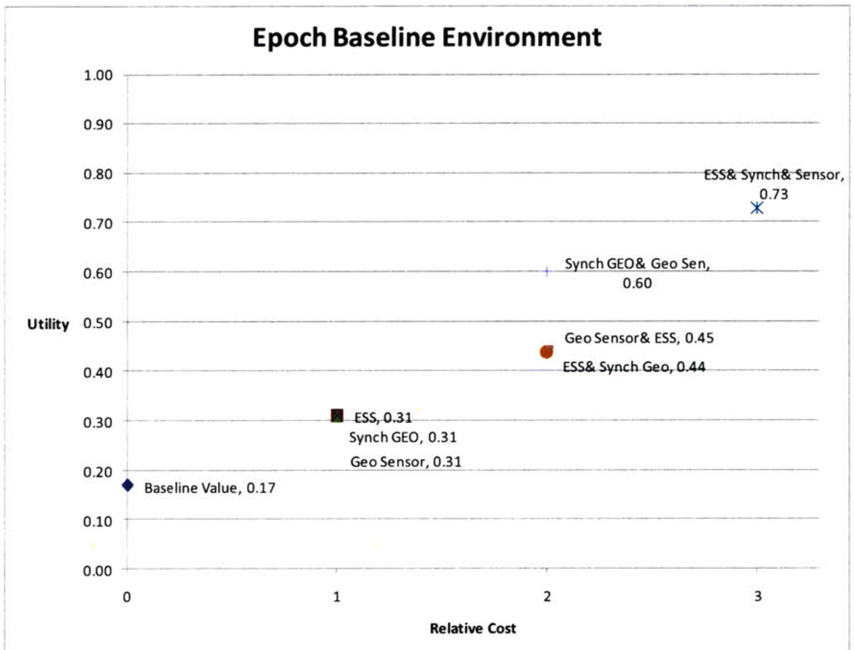


Figure 4-14: Epoch Baseline Performance

The baseline simulation results, Figure 4-14, display expected utility outcomes of each of the candidate architecture future states. The desired area of performance is up and to the left, the highest utility possible for lowest cost. The boundary formed by each of the highest performing architectures at each level of cost is the Pareto Front.

4.6.2 Epoch A Analysis: Faster Change of Mission

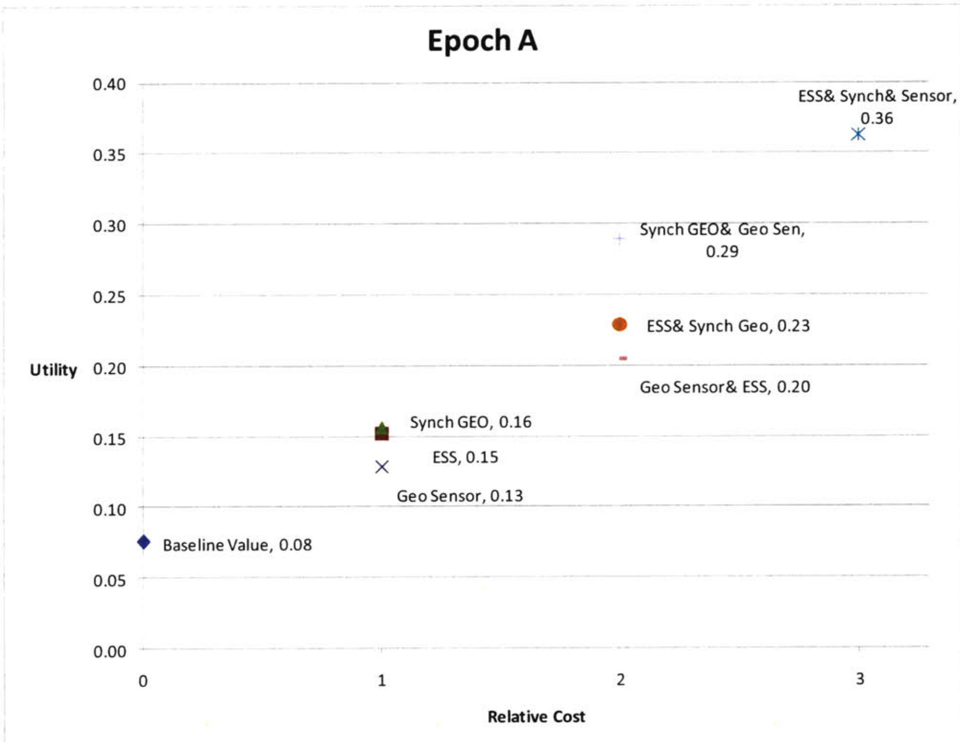


Figure 4-15: Epoch A Performance- Faster Change of Mission

Epoch A is a much more difficult set of environmental conditions for the AGE to provide utility to the stakeholders. The entire Pareto front has shifted down. Also, the slope of the front has increased, meaning the relative benefit achieved by each increment of investment into the enterprise has greater return in this epoch. The other notable change is the increased dispersion around the two ESS hybrid architectures. The speed of information dissemination and synchronization is paramount in these conditions. Value is lost if a sensor is implemented without the required increase in the speed of information dissemination. This problem is less apparent in the baseline epoch, since a slower speed of dissemination, though reducing value has less impact since the unit does not transition to new terrain as quickly. The difference between Epoch A and the Baseline Epoch is similar to the difference between World War I with static trench warfare, and World War II, with fast moving "blitzkrieg" tactics. Interestingly, the Army map service had overestimated the need for maps in WWI, and required huge increases in capacity during WWII.

4.6.3 Epoch B Analysis: More Dynamic Terrain

The second epoch variable, the rate of change of the terrain, captures the characteristics of the terrain itself that makes it harder to maintain accurate and current geospatial information of a location. If the terrain changes quickly, the speed with which utility decreases drives the deterioration of the brigade's geospatial information. This is modeled by increasing the rate of exponential decay of the benefit of geospatial information at each echelon of the brigade.

Epoch B is very dynamic terrain. This might represent an urban area where friendly, enemy or local population actions change the terrain. Examples of changes are the emplacement or movement of large obstacles, change in building uses and government support infrastructure, or changes from friendly kinetic operations. This is a much more difficult epoch for the geospatial enterprise to deliver value to decision makers, since the enterprise must "keep up" with the high speed of the changing terrain. Figure 4-16 shows the performance of each of the future state candidates in Epoch B.

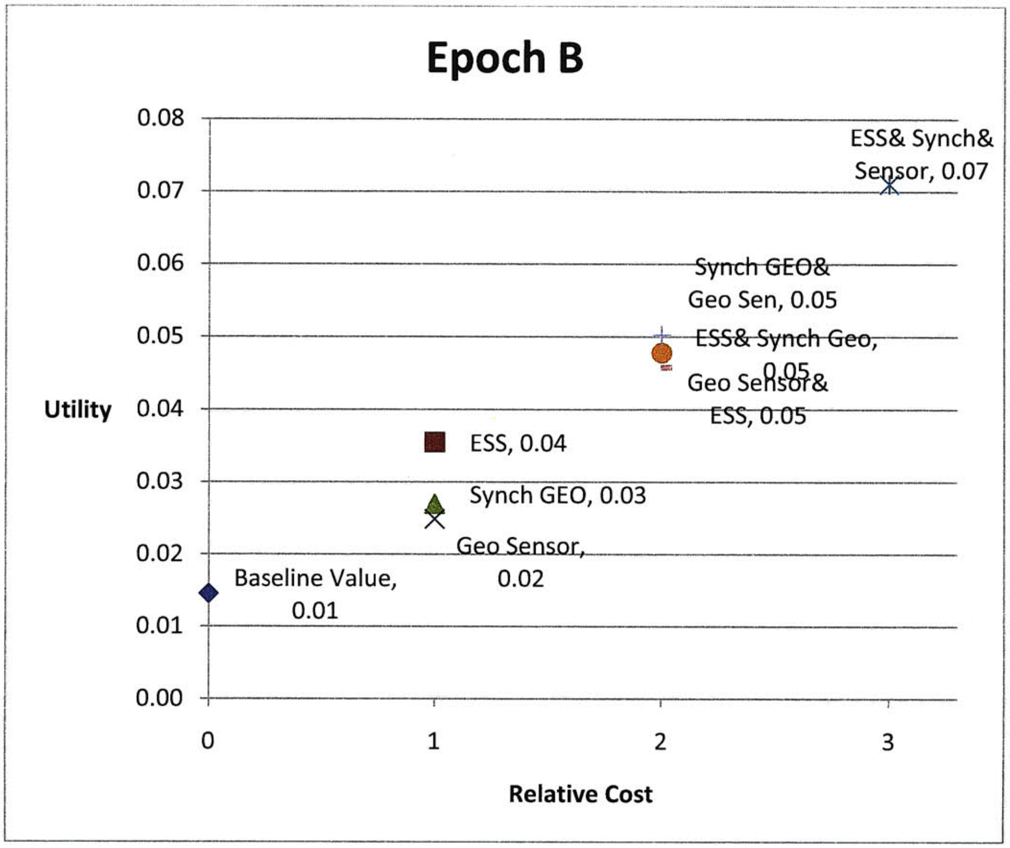


Figure 4-16: Epoch B Performance- More Dynamic Terrain

4.6.4 Epoch C Analysis: Less Dynamic Terrain

During Epoch C, the military operations occur over terrain that changes much more slowly. This might be thought of as operating in a desert, which does not have high speed erosion of wadis or shifting sand dunes to change the landscape. Since the terrain changes slowly, the "shelf life" of geospatial information increases as well, increasing the ease with which the AGE can deliver value to tactical decision makers. Figure 4-17 shows the performance of the candidate future state in Epoch C. The significant difference here is the poor relative performance of the geospatial sensor system. This intuitively makes sense, since an increased ability for the brigade to continually "re-map" terrain that is changing very slowly and will produce less value with each collection.

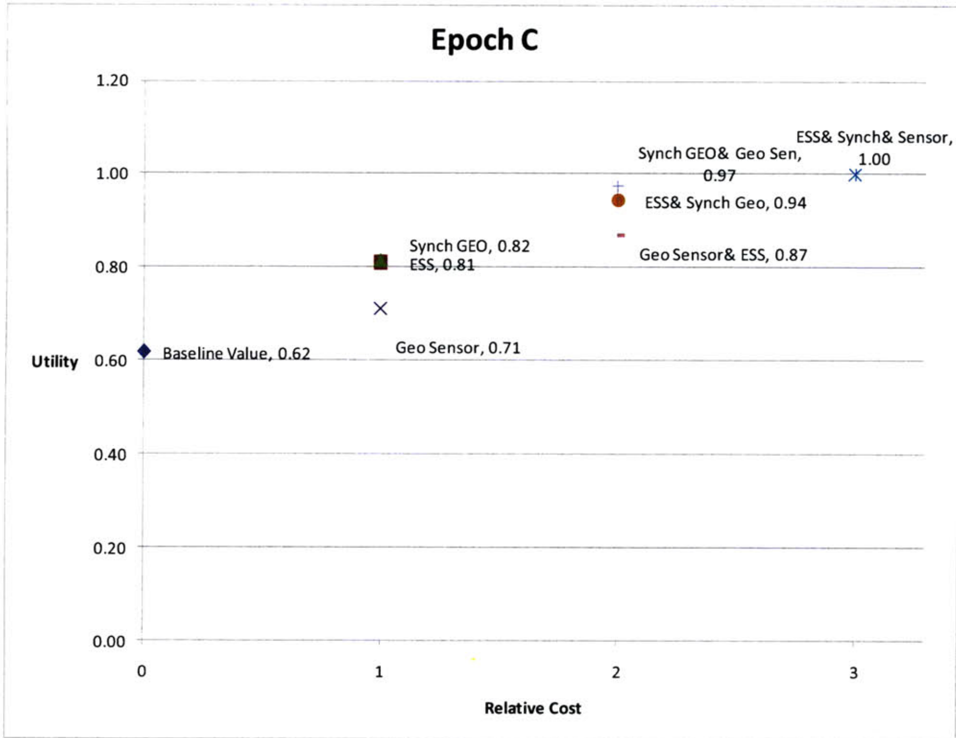


Figure 4-17: Epoch C Performance- Less Dynamic Terrain

4.6.5 Era Analysis

Future Eras are defined by stringing together several Epochs which have a high probability of occurring in a particular sequence. Era analysis allows the Enterprise Architect to simulate the performance of a candidate future state over a longer time horizon. Based upon current trends, the most likely progression of environmental conditions will migrate toward Epochs A and B. As the world continues to develop, the rate of change of urban terrain continues to increase. Also, the speed of operations will most likely increase as well. There will be less political support for protracted wars in the same geographic region, given the high cost of a prolonged military effort for seemingly less international benefit. Given, that Epochs A and B dominate, future environmental conditions, there is a shift toward a more difficult future geospatial context, requiring continued improvements to the geospatial capability to provide the same level of utility to decision makers.

4.7 Recommended Future State Army Geospatial Enterprise Architecture

A brief discussion of the recommended future state enterprise architecture is discussed here, with further discussion of specific characteristics of a future state architecture in the following sections.

The Department of Defense is entering a period of greater resource constraints due to a politic desire to reduce defense spending. In Defense Secretary Gate's speech at the Eisenhower Presidential Library the Secretary warns of the need to reduce spending, "Eisenhower said he was troubled by the tendency to "pile program on program" to meet every possible contingency." (Gates 2010) He indicates that the current priorities, metrics and initiatives must be synchronized and well architected to achieve better value for the Country. The Secretary continued, "The Defense Department must take a hard look at every aspect of how it is organized, staffed, and operated – indeed, every aspect of how it does business." (Gates 2010)

Though the "upstream" resource constraints were not modeled explicitly in the System Dynamics simulation, the cost of transformation is still considered. Given these ensuing fiscal constraints, a longer, less aggressive AGE architectural deployment is warranted. The transformation should begin by implementing the Every Soldier a *Geospatial* Sensor architectural future state. Modest effort aimed at capturing the geospatial information during military operations will enable the benefit of geospatial information already inside the enterprise, but which is currently left at the patrol level. Very quickly the implementation of the senior geospatial officer and synch geo future state architecture becomes paramount. As more data is available through additional ESS capture techniques, the lack of synchronization will continue to increase, leaving more of the value of the geospatial information unleveraged. Finally, the geospatial sensor at brigade level should not be pursued in the near term. Such a large sensor program might raise the limits of geospatial capability, but could also cause negative reaction to the high cost of the sensors and stress already limited aircraft resources for flight hours of collection.

4.8 Considerations for Enterprise Transformation

The Army Geospatial Enterprise must consider several factors as it determines a possible enterprise transformation endeavor: first to be considered should be the way in which the decisions surrounding the architecture are presented to Army leadership. A method of simplistic decision parameterization has proven effective in other similar decisions. A beneficial outcome of the value driven design method is that much of the design work can be done "behind the scenes" of the higher level enterprise decision makers that actually set the budgeting priorities. Even though the design approach was not alternative based, the architectural decision making could now be designed around a discrete set of design variables that create alternative future architectures at differing resource levels. The simulated results of the desired attributes of the enterprise based on the possible future states can help upper level management make difficult resource decisions and achieve the best possible future state within a fiscally constrained environment.

4.9 Observations from the Future State Analysis

In light of the candidate architecture analysis, several observations about the nature of Army geospatial operations emerge. The following sections detail some generalizations for geospatial information within the AGE.

4.9.1 A Portfolio Approach to the Geospatial Portion of the Information Domain

Up to this point the analysis has been focused on the geospatial foundation layer, a specific portion of the geospatial information within the brigade. The geospatial foundation layer defines the COP, but there is other geospatial information within the brigade. There is a spectrum of geospatial information across the information domain from sensor data to reports in natural language. Is one level of information more beneficial than another? An emerging theme from the research indicates that a balanced approach to the geospatial information domain is necessary. The degree to which effective mental models are created in the cognitive domain of the tactical decision maker requires a varied array of geospatial information. This depends on the context and the preferences of the decision maker.

The goal should be to achieve freedom of movement within the information domain which can support cognitive flexibility, allowing adaptation to the wide variations of an open system battlefield. Technology should not force tactical decision makers into a predetermined box within the information domain, but should enable increased speed of movement within the information domain subject to appropriate behavior shaping constraints (Vicente 1999).

Recent operations in Iraq and Afghanistan have prompted a shift in military planning doctrine away from the highly structured task oriented Military Decision Making Process, toward a more flexible creative problem solving method, simply named "design." The geospatial community should mirror this approach with a flexible geospatial foundation layer that spans the information domain in such a way as to support the open system concept. Why is this necessary? Flexibility of geospatial information allows for the enterprise to be flexible to the "geospatial tastes" of a wider range of tactical decision makers. It also allows the enterprise to be adaptable to a greater range of operational information requirements.

A huge prerequisite to enable the effective use of geospatial information across the information domain is the training of all tactical decision makers on the breadth and applications of geospatial information. This type of training impacts the knowledge domain of the enterprise by increasing the capability of the Soldiers, leaders and planners to transform geospatial information into mental models of the terrain thus producing good situational understanding.

There is a push within the Army's geospatial community to overvalue the tier three, high level products, which are closest to the cognitive domain. It is true that this information has the greatest value for the decision maker, since these contain "pre-processing" of the lower level information by either human analysts or computer algorithms. The problem is that built into this processing are the risk tolerances of the decision maker, based on the context of the larger decision environment. This level of information increases the speed with which commanders can make decisions, but it removes the benefit of experienced decision making, where the commander brings together context and constraints in a way that less experienced analysts or algorithm developers cannot. This is why the context provided by the lower, tier one products have applicability to command decisions, and a balanced portfolio perspective is needed. The full geospatial context is critical for commanders at every echelon to demonstrate creativity, evaluate risk tolerance in tactical decision making, and allow the commander to leverage their expert experiential decision making advantage.

The goal of geospatial research should not be to drive all information that commanders and staff interact with into tier three, but rather provide the commanders and staff freedom of movement within the geospatial information domain. There is great value in the ability of a commander to explore large, general use foundation data, and then quickly transition to specific mission decision information, and then back to the greater foundation context. This mobility within the geospatial information domain increases the trust and confidence of the commander in the tier three analysis and information.

For example, below is a hypothetical discussion.
GET NCOIC: "Sir, the bridge is out along our main avenue of approach, the best bypass is long ASR Beaver."
CDR: "Let me see the big picture."
GET NCOIC shows the commander the tier two analyses over the AO that developed ASR Beaver as next best option.
CDR: "How do we know this information?"
GET NCOIC "Here is my geospatial foundation data, it was updated by sensor X this morning using this perspective and approach" [provides basic raw sensor data]
CDR: "Critical information, I agree with your assessment, but instead of using ASR Beaver, which is longer and close to enemy observation, my intent is to conduct a river crossing operation. It increases the risk of the mission, but may increase target payoff by leveraging the element of surprise."

The commander conducts mission tradeoffs using expert decision making and data, information and knowledge from across the spectrum of geospatial information domain. The ability of the GET NCOIC to span all levels of the domain is critical to informed tactical decision making.

Table 4-6: Effects of Shift in Complexity and Uncertainty

Spectrum of battlefield comlexity	
closed system	open system
less uncertainty of conditions	greater variability of conditions
fewer cognitive domain excursions	more cognitive iterations in VSM
procedural task execution	creative problem solving
MDMP	Design
tighter sensor to shooter link	more nodes along sensor to shooter chain
narrow geospatial information needs	full portfolio of geospatial information
→ trend of current operating environment	

As battlefield complexity continues to increase, the ability for military leaders at all levels of command to make informed decisions is more difficult. The Army recently unveiled a new method to plan and manage military operations. The old method was the Military Decision Making Process (MDMP), which is a scripted step by step process to develop, compare and implement a course of action. The new method, called "Design," leverages the creativity and expert decision making capabilities of the commander in a less constrained process, in order to increase the flexibility and creative problem solving ability needed to tackle increasingly complex military missions.

4.9.2 The Sensor to Shooter Link and Its Impact on Geospatial Operations

The sensor to shooter link is the time it takes to understand the situation to the time it takes to act. The length of the value stream from sensor to shooter is measured in both time and number of activities that take place along the pathway. The less time that information takes to get through the value stream, typically the greater probability of success of the tactical action. The value adding activities are automated processes acting on the information or an excursion into the cognitive domain of an analyst as described above. The increase in information quality from the activities along the value stream will increase the probability of success of the mission. Therefore, the speed and coordination of these activities will increase the quality, and therefore utility and value of the geospatial information.

A way to approach the analysis of these two methods is to ask the question "what is the optimal length of the value stream?" The fielding and implementation of Tactical Ground Reporting (TIGR) addresses a similar need currently, so comparison to that system is appropriate. TIGR is an information system that allows patrol leaders to input information about the mission and patrol events directly into a computer system. This allows them to query information later about missions conducted in the past over the same area of operations. The information can be shared with other units, commanders and planners to allow them to better understand the terrain, enemy activities, and local population.

"The sea change created by TIGR is that the junior officers and infantrymen have eliminated the middleman — the intelligence officer — and they can put the information they, and others, have gathered to immediate use, Maeda [Mari Maeda, project manager for TIGR] said. Patrol leaders now feel that they are getting something out of the reports they are submitting. 'We have closed the [intelligence gathering] circle,' she said. 'The soldier is going to generate the report, [and] all that information is now available to him at his fingertips.'" (Magnuson 2007)

Is this reduction of "middlemen" from intelligence officers to geospatial analysts the goal of network centric warfare and Army modernization? This approach does reduce the time from sensing the battlespace to acting in the battlespace. Within the area of geospatial information, the time reduction may come at a cost. This change in the value stream of geospatial foundation data compresses the cognitive requirements as outlined in Figure 2-11.

4.9.3 Information "Pruning"

Removing geospatial information from the information domain that is of least utility increases the opportunity for decision makers to utilize the best information to most quickly positively impact their cognitive domain, and therefore make the best tactical decisions possible.

If it is true that commanders want to have access to all tiers of geospatial information, then the "information logistics" required to support geospatial operations will continue to grow. To continue the logistics analogy, the Army uses two sets of information to drive what spare parts are carried with a unit into battle. The Prescribed Load List (PLL) has demand driven and command drive components. The demand driven portion of the spare parts list is generated by the number of demands occurring within the unit over a set period of time. The command driven portion allows the commander to arbitrary add a percentage of items to the list, usually low density items that may not meet the demand driven requirements, but which the commander has identified are critical to the mission he is conducting. This dual system allows for command preference and tailored mission perspective while at the same time imposing some level of logistical restraint and fiscal responsibility. Perhaps there is a need for this dual approach within the geospatial information arena. The personality of the commander impacts the information needs that will enable their personal military decision making, thought processes, and mental models. Catering to these information needs is absolutely important. While at the same time is important to drive standardization of geospatial information products and databases to improve interoperability and constrain costs.

Well informed commanders may voluntarily reduce their geospatial information footprint by pruning the unnecessary data sources and product types in order to their information footprint.

4.10 Future State Summary

The geospatial information has the potential to be the key unifying commodity within command and control and across all Warfighting Functions. Given the dynamic conditions surrounding the AGE, a value driven design approach has great potential for increasing the enterprises value delivery over time. A holistic perspective of the "knobs" available to enterprise leadership in conjunction with deep understanding of the attributes of the stakeholders enables effective transformation. The three future state alternatives investigated here are only a small portion of the design space, continued analysis and technology adoption will continue to increase the performance of the enterprise.

5 Conclusions and Recommendations

The purpose of this chapter is to provide a summary of the analysis and recommendations for the Army's Geospatial Enterprise. The findings from the future state analysis conducted in chapter four yield a set of heuristics for transforming the Army Geospatial Enterprise. The heuristics help to focus the architecture efforts of AGE organizations and help prioritize the limited resources within the Army Geospatial community. The chapter ends with a discussion of future work within the research area of the AGE.

5.1 Findings and Heuristics

Heuristics provide the Enterprise Architect with a set of guiding principles which help to provide clarity and direction while ambiguity and uncertainty shroud the enterprise. The following basic heuristics help to inform the architects of the AGE.

5.1.1 Considerations for Harnessing Soldier Input to the Geospatial Foundation Layer

The most cost effective method to increase the geospatial foundation layer at the brigade level is to employ the Every Soldier as a *Geospatial* Sensor concept to directly update the geospatial foundation layer. This change to the AGE will quickly increase the amount of beneficial geospatial information at each layer in the brigade with access to the information obtained by operations in the battlespace. There are significant limitations to this approach. First, there is the issue of how the information is propagated back through the enterprise. The approach modeled in this research assumes a direct linkage from the mission back to the AGE, meaning the information does not pass back through the cognitive domain of the operator requiring synthesis and reporting, or of the terrain team for authentication. The information is directly sensed through some automated means and available across the enterprise instantaneously. The solution for direct ESS enabled geospatial foundation update could be achieved through many technical means. The method of technical implementation will impact the amount of information that flows back into the enterprise. For example, each Soldier could carry a networked GPS enabled camera system, use structure from motion from vision aided navigation that updates GF, or simply vehicle statistics to show route and speed. Better harnessing of the geospatial collection capacity during operations is a relatively low cost architectural adjustment with potentially large benefits.

5.1.2 The Potential Benefit of a Brigade Level Geospatial Sensor

The addition of geospatial sensing capability within the brigade has a great potential for increasing the utility of the geospatial foundation layer, the utility of the COP, within all warfighting function areas of the brigade. Of the three alternatives types analyzed in the research, this approach has the greatest "upper bound" since the approach actually brings "new" information into the system, rather than just increasing the utility of the information that is already within the enterprise. There are several points of caution for this approach.

First, in order to harness the full value of a geospatial sensor capability, the enterprise must first develop the capability to synchronize the new information more quickly and efficiently. The implementation of the hybrid senior geospatial officer "synch geo" future state alternative is one method to improve the process and knowledge areas of the enterprise to enable more efficient utilization of the geospatial sensor capability. Second, as the level of effort and capability of the geospatial sensor increases there are increasing returns on that investment, until a break point, after which the benefit of the new geospatial information quickly hits a point of diminishing returns as the utility of the tactical decision maker is saturated. This saturation point varies significantly with the type of tactical mission and the type of terrain the mission operates over. Though in the current state the fear of over production of quality within the geospatial foundation data seems far off, one can easily imagine a new sensor technology that could surpass the quality needs of the tactical decision maker for some types of conflicts and relatively static and simplistic terrain. The final point of caution for consideration when implementing a new geospatial sensor system is of the three future state architecture alternatives, the geospatial sensor is the most sensitive to environmental changes in possible future epoch conditions. By itself, the geospatial sensor is not very "value robust." One can imagine an expensive sensor system sitting on the shelf collecting dust if the terrain was not dynamic enough to warrant the effort and risk to conduct continuous collection operations (Epoch D). Also, a geospatial sensor capability at the brigade level would be obsolete if operations were moving at such a rapid pace that the information delays within the enterprise overcame the benefit of the geospatial sensor (Epoch A). Overall, an increased geospatial sensing capability has great potential in increase the utility of the foundation layer, but this capability must be implemented within changes to the larger enterprise structure, as well as with a close understanding of the probability of the nature and location of future operations.

5.1.3 The Negative Effect of Narrow Focus

If enterprise development and improvement efforts focus too heavily on sensor technology and implementation, greater effort will be expended in the long run, with much of the benefit unrealized. While, solely focusing on improving the geospatial information flow internal to the brigade structure will meet utility limits quickly and leave tactical decision makers lacking required knowledge of the terrain. A balanced approach should be pursued, beginning with improving the internal geospatial information flows. This improvement must also begin with the process, organization and knowledge enterprise views, rather than the information technology perspective. Though synchronization and increased speed in information flow can be influenced by information technology improvement, data standards and proper geospatial system evolution, initiatives such as senior geospatial personnel and geospatial knowledge provisioning for all Soldiers is a necessary initial condition to drive information technology development and adoption.

5.1.4 Balancing Standards with User Innovation

The future state AGE must not stifle the innovation of the geospatial practitioners across the Army. There is a huge need for standardization, authoritative data structures and products, synchronization, and compliance within the geospatial portion of battle command. But the innovation of new products, data fusion, and collaboration on the battlefield today continues to push forward the great impact that geospatial operations has to good military decision making. There should be some care taken to enable continued "user innovation" in the future state architecture.

There are two considerations for maintaining innovation within an increasingly standardized enterprise. First, the enterprise should allow for nonstandard processes, products and systems to exist in defined areas of the enterprise. Testbeds, experimentation efforts and new technology development must occur across the enterprise, not only deep within research labs under lock and key. The field users, both producers and consumers of geospatial information, should have the opportunity to operate outside the typical standard cookie cutter configuration for give periods of time without a prohibitive waiver processes. Capturing these experiences back within the enterprise as a whole will spread new user needs and new solution ideas. Second, the enterprise should keep a tight pulse on the cycle time of the standards evolution within the enterprise. Stagnant policies will unnecessarily stifle technology adoption and innovation within the enterprise.

5.1.5 The Architecting Effort for the AGE Will Never Be Complete

The AGE is not static. There are components entering and leaving the enterprise. There must be a continuous flow of informed design decisions, and the architecture must evolve. Informed architecting requires reflection and continual effort. The job of the enterprise architect and the EA effort is not complete with execution of a transformation plan. Iteration must continue based on thoughtful reflection and analysis. The predicted future Epochs and Eras will evolve and change, impacting value identification and delivery. Architects tend to be consumed by the process of architecting the deliverables so that they miss the bigger picture. The architect must consider how the enterprise changes over time. When the architect reflects (as almost an outsider) on the architecture, the longest broadest time horizon should be used to understand the full context (over time.) Enterprise architecting is never "done." There must be continual reflection up on the enterprise, architecture, and value creation within changing needs and environmental contexts.

5.2 Future work

The values and attributes of the stakeholders need to be refined with further study and utility elicitation. The system dynamics model could be expanded to insure that the model represents all of the complexity and interactions with the enterprise, not just at the enterprise boundary at the brigade level. Also the model requires extensive validation beyond the scope of the present study, most likely requiring extensive interviews, surveys, and experimental data reaching a broader set of the stakeholders.

5.2.1 Additional Survey Work

The focus of the survey was on the Army Geospatial Enterprise boundary at the BDE level and below. There are many individuals that reside along that boundary and interact with the enterprise in many ways. The survey engaged a well positioned subset of all the individuals impacted by the enterprise. The AGC leadership and terrain team Soldiers were chosen to act as a proxy for several of the other stakeholder segments along the boundary. A larger more comprehensive survey could be conducted to leverage more perspectives along this boundary. Also, similar investigation could be conducted across the value stream of the enterprise.

5.2.2 Process for Evolving the Model

Some informal iteration were performed, such as the refining of future state alternatives based on intermediate results of the initial model, but much more iteration is required in order to capture the full breadth of stakeholder needs within the final transformation effort. The model requires validation of both structure and the values of exogenous variables. In order to validate the system dynamics model, the

Another consideration is the significant amount of abstraction contained in the model of the AGE boundary. Individual geospatial products, databases, and sources are all treated equally, aggregated into a single geospatial utility. But the benefit derived from each of the available products might evolve during the operation. Understanding this evolution could help geospatial information producers more accurately target the most needed products over the duration of the deployment or mission.

Finally, the model does not explicitly determine the cost of implementing the candidate future state architectures. A refined cost model based upon lifecycle system, manning, and training costs is needed to more accurately compare the costs associated with each future state architectural approach.

5.3 Conclusion

The results do not attempt to optimize a desired future architecture for the AGE, but rather inform decision making early in enterprise development to assist the Army geospatial leadership to understand possible transformation trajectories. Several candidate architectures are developed and evaluated within the context of dynamic environmental conditions. Given lower resource availability, the best architectural choice is to focus on capturing the geospatial information obtained by Soldiers as they travel around the area of operations, learning about the terrain from experiences and interactions with local populations. As the level of funding increases, there is a significant jump in the benefit of geospatial information if a geospatial sensor is deployed, while at the same time synchronizing information dissemination and use within the brigade. Aligning resources appropriately to a coordinated geospatial architectural approach is important to future military operations as new technologies continue to require increased geospatial information quality.

Appendix A: Abbreviations and Acronyms

Acronym	Definition
215D	Geospatial Engineering Technician
21Y	Geospatial Engineer
AGC	Army Geospatial Center
AGE	Army Geospatial Enterprise
AO	Area of Operations
ASAALT	Assistant Secretary of the Army for Acquisitions Logistics and Technology
AWR	Airworthiness Release
BC	Battle Command
BDE	Brigade
BN	Battalion
C2	Command and Control
C4I	Command, Control, Communications, Computers, and Intelligence
CCIR	Commander's Critical Information Requirements
CHPPM	U.S. Army Center for Health Promotion and Preventive Medicine
CIB	Controlled Image Base
CIO	Chief Information Officer
CJMTK	Commercial Joint Mapping Tool Kit
CO	Company
CONOPS	Concept of Operations
COP	Common Operating Picture
CP	command post
DCGS-A	Distributed Common Ground System - Army
DoD	Department of Defense
EA	Enterprise Architecture
ES2	Every Soldier as Sensor
GET	Geospatial Engineering Team (same as terrain team)
GF	Geospatial Foundation Data
HQ	headquarters
IC	Intelligence Community
ISR	Intelligence Surveillance and Reconnaissance
IT	Information Technology
JIIM	Joint, Interagency, Intergovernmental, and Multinational
LIDAR	Light Detection and Ranging
NATO	North Atlantic Treaty Organization
NCW	Network centric warfare
NG	Northrop Grumman
NGA	National Geospatial-Intelligence Agency
NSG	National System for Geospatial-Intelligence

OGC	Open Geospatial Consortium
OPTEMPO	Operational Tempo
PM	Program manager
PME	Professional Military Education
QDR	Quadrennial Defense Review
RFI	Request for Information
RIP TOA	Relief in Place, Transfer of Authority
SAIC	Science Applications International Corporation
TLM	Topographic Line Map
USGS	United States Geological Survey
VITD	Vector Interim Terrain Data
VSM	Value Stream Map
WFF	Warfighting Function

Appendix B: Survey Questions and Full Results

The survey was sent to 300 Soldiers within the Army Geospatial military occupational specialties. The goal of the survey was to better understand the current state of the Army Geospatial Enterprise.

Some continuing questions:
How should the geospatial foundation layer be considered? When should information be part of the foundation layer when should updated information be part of a layer on top of the foundation layer. When the information contradicts information in the foundation layer, that information should update the geospatial foundation, rather than reside in a layer which contradicts the foundation. Therefore, if building is on the map, but does not exist, the foundation layer should be updated.

Geospatial Community Survey:

Welcome to the survey and thank you for your time.

You have been asked to participate in this survey to help gather information about the state of geospatial operations within the army. Information gathered in this survey will contribute to a research study being conducted by CPT Jed Richards in conjunction with study at the Massachusetts Institute of Technology (MIT). The purpose of the study is to identify how geospatial information is being used in current military operations and the utility of different types of data sources.

Please Contact CPT Jed Richards with any questions, comments or concerns via e-mail at jed.richards@us.army.mil.

If you feel you have been treated unfairly, or you have questions regarding your rights as a research subject, you may contact the Chairman of the Committee on the Use of Humans as Experimental Subjects, MIT, Room E25-143b, 77 Massachusetts Ave, Cambridge, MA 02139, phone 1-617-253-6787.

Study Title: Army's Geospatial Architecture: delivering Geospatial-Intelligence of complex and urban terrain to the dismounted Soldier

- This survey is voluntary. You have the right to not answer any question for any reason.
- You will not be compensated for completing this survey.
- The information you tell us will remain confidential. Statements will not be attributed to any individual.
- This survey is being conducted at the UNCLASSIFIED level. All comments must remain at the unclassified level.

If you believe you have a discussion that pertains to the topic that requires classified conversation, please contact CPT Richards via email (jed.richards@us.army.mil) to set up a special meeting to accommodate that information.

Begin Survey

Geospatial Community

Comments (as needed):

ADMINISTRATIVE

1. What is your rank?		
	Click on right to select	
2. What is your geospatial specialty (MOS / GA, etc...)?		
	Click on right to select	
3. What is your current organization / unit of assignment?		
	Click on right to select	
For the following questions: reflect back to your most recent relevent experience (training/deployment)		
4. What was the most common mission of your unit / organization?		
	Click on right to select	
5. What was the most important mission YOU have been/were conducting?		
	Click on right to select	

DATA ACQUISITION / GENERATION

6. Which of the following data sources did you use (choose the 5 most important)?		
#1	Click on right to select	
#2	Click on right to select	
#3	Click on right to select	
#4	Click on right to select	
#5	Click on right to select	
7. How often did you use the data sources chosen above?		
	Click on right to select	Click on right to select
	Click on right to select	Click on right to select
	Click on right to select	Click on right to select
	Click on right to select	Click on right to select
	Click on right to select	Click on right to select
8. How important / beneficial to your mission was each data source chosen above?		
	Click on right to select	Click on right to select
	Click on right to select	Click on right to select
	Click on right to select	Click on right to select
	Click on right to select	Click on right to select
	Click on right to select	Click on right to select
9. How effective were the communications links available at getting you each type of data you selected above?		
	Click on right to select	Click on right to select
	Click on right to select	Click on right to select
	Click on right to select	Click on right to select
	Click on right to select	Click on right to select
	Click on right to select	Click on right to select

DATA MANAGEMENT AND STORAGE

10. Who managed the geospatial information (physical storage) at your location?		
	Click on right to select	
11. Did others outside of your organic organization have access to this data (electronically)?		
	Click on right to select	Other BCTs operating nearby
Please list examples of these individuals/methods used/effectiveness?		Division and Corps Staff
	Insert comments here	Attached "enablers" (CA, SOF, etc)
GEOSPATIAL DATA PRODUCTION		
12. Rank order the five most common products you produce (or have produced) during operations?		
#1	Click on right to select	
#2	Click on right to select	
#3	Click on right to select	
#4	Click on right to select	
#5	Click on right to select	
15. On average how many products did you produce a week?		
	Click on right to select	
13. Typically who tasked you?		

	Click on right to select	
14. Who were your primary customers (please list below)?		
	Insert comments here	

DISPLAY AND REPRODCUTION

16. Rank order the primary distribution methods for geospatial products?		
#1	Click on right to select	
#2	Click on right to select	
#3	Click on right to select	
Other	*Insert comments here*	
17. Rank order the file type in which you post / distribute products.		
#1	Click on right to select	
#2	Click on right to select	
#3	Click on right to select	
Other	*Insert comments here*	

GEOSPATIAL UNDERSTANDING AND MILITARY DECISION MAKING

Please answer questions below on a scale of 1 - 5 (5 being the best)

18. How well do you think your boss (commander or other) understood the effects of terrain on military operations?		
	Click on right to select	
19. How effective do YOU feel your geospatial products where towards your unit's mission?		
	Click on right to select	
20. How well were your geospatial operations perceived by the maneuver forces in your unit?		
	Click on right to select	
21. How did your commander perceive his/her geospatial support?		
	Click on right to select	
22. How did the planning staff perceive geospatial support		
	Click on right to select	
23. How did the intelligence section / staff perceive geospatial support?		
	Click on right to select	

General Comments

24. What was working well, your biggest success stories?		
	Insert comments here	
25. What were your biggest frustrations with geospatial operations?		
	Insert comments here	

Answerone																							FOR ALL
Click on right to select																							0
Contractor																							0
Government Civilian																							0
COL+																							0
LTC																							0
MAJ									1														1
CPT																							0
1LT																							0
2LT																							0
CW5																							0
CW4						1																	1
CW3		1			1																		2
CW2				1																			1
WO1																							0
CSM																							0
SGM																							0
1SG																							0
MSG																							0
SFC	1							1															2
SSG							1			1									1				3
SGT			1								1											1	1	4
SPC												1	1	1	1	1	1				1			7
PVT																				1				1
																							0
																							0
21Y - Geospatial Engineer	1		1				1	1		1	1	1	1	1	1	1	1	1	1	1	1	1	1	18
215D - Geospatial Information Technician		1		1	1	1																		4
21A - Engineer Officer									1															1
35G - Imagery Analyst																								0
350F - All Source Intelligence Technician																								0
350G - Imagery Intelligence Technician																								0
35C/D - Intelligence Officer																								0
Civ - Geospatial Analyst																								0
Civ - Imagery Analyst																								0
Civ - Geospatial Support (general)																								0
																							0
																							0
EAC Topographic Engineer Company (70th or 100th)		1										1	1	1			1							5
Corps Terrain Team, GPC / P&C / Topo Det.	1				1						1											1		4
1st Infantry Division (Mechanized)																		1						1
1st Armored Division																								0
1st Cavalry Division																								0
2nd Infantry Division																								0
3rd Infantry Division (Mechanized)																							1	1
4th Infantry Division (Mechanized)																								0
10th Mountain Division (Light)																								0
25th Infantry Division (Light)																								0
82nd Airborne Division																					1			1
101st Airborne Division (Air Assault)				1																				1
US Army Engineer School (Fort Leonard Wood)						1																		1
US Army Intelligence Center (Fort Huachuca)																								0
National Geospatial-Intelligence Agency (NGA)			1					1	1															3
NG Team										1					1	1			1					4
5th SFG (A)							1																	1
																							0
Route Clearance												1											1	2
Area Security / Patrols				1			1																	2
Cordon and Search / Raids		1	1																					2
Fixed Site Security																								0
Civil-Governmental Support					1					1														2
Reconstruction								1						1			1			1				4
Disaster Response											1								1					2
Offensive Operations	1					1									1	1					1			5
Defensive Operations													1					1				1		3
																							0
																							0
suitability (ie HLZs products)											1				1	1		1						4
stability (ie LOS, viewshed)			1	1			1					1					1	1		1	1			8
mobility (ie route recon)	1	1			1	1		1		1			1	1				1				1	1	11
																							0
																							0
Standard NGA maps TLM, JOG etc (RFP, CADRG...)		2		5	5	2	2	3		5	1	5	4	5	5	4	2	4	5	5	2	5	4	75
CIB (1meter or 5meter)		3				4	3	2		3	4				4								2	25
DTED (level 0,1,2) and SRTM		1		6			5	1		1	4					2	5	1			5	4	1	36
vector feature data (VITD)	1					1							2	1	1	3	1	3		3	4	3	3	26
LIDAR (Light Detection and Ranging 1meter)	6	4	5		4		1	4			5	2	3			2	6	2		6				42

UAV full motion video feeds																								0
High Resolution EO (Buckeye, highlighter etc.)	5	5	4	3			4		4		2	3		3		5		5	3	3	1	3	5	55
Urban Tactical Planner (Shape files or TT fys)	2		1										3						4					10
Commercial Imagery	3		3	2	3	1		5	3	4			5	4	2		3		1	1				40
National Assets (NTM)			2		1	5			5	1				2							3			19
Any geospatial database (please list name/source)				1	2				3	3					3				3					14
																								0
																								0
Terrain Team NCOIC/OIC	1	1	1	1	1	1	1	1		1	1		1		1	1	1	1	1		1	1	1	19
S2														1										1
S3																								0
Brigade Engineer																				1				1
S6 DB manager																								0
Other									1			1												2
																								0
																								0
Yes	1	1	1	1	1	1		1	1	1	1				1	1				1	1	1	1	16
No							1					1	1	1			1	1	1					7
																								0
																								0
ITC density plot		1	1		1	1	1	1	1			1		1			1					1		11
Line of Sight			1	1				1		1		1	1	1		1	1	1		1		1	1	13
View Shed	1		1	1	1	1	1				1	1	1			1	1	1					1	13
Cross Country Mobility						1					1			1	1		1	1		1	1		1	9
Obstacle Overlays			1		1	1	1	1						1		1							1	8
Route Analysis	1		1		1	1	1	1		1	1	1	1	1	1	1	1	1	1	1	1	1	1	20
Slope Plot					1			1			1									1	1			5
Other (please list) feel free to attached UNCLASS example	3	4							4	3					1	1		1		1				18
																								0
																								0
																								0
100+	1	1				1																		3
80-100								1										1				1		3
40-80			1				1			1													1	4
10-40				1	1				1		1	1	1			1					1			8
0-10														1	1		1		1	1				5
																								0
																								0
Brigade Commander								1													1	1		3
Brigade XO			1																					1
Brigade S3					1					1	1		1				1							5
Brigade S3 Planner (shop)																							1	1
Engineer	1											1		1										3
Fires																								0
S6																								0
Aviation															1	1								2
Other		1		1		1	1		1									1	1	1				8
																								0
Paper copy	5	5		3	3	5	5	5		5	5	5	5	5	5	5	5	5	3	5	5	5	5	99
Email				1				3		1		3	1	3	3	1	3		5		1			25
Thumb Drive	1	1	3						5															10
Website posting	3	3	1	5	5	3			1	3	3	1	3	1			1	1		1	3	3	3	44
External Hard Drive (250GB+)						1	3		3														1	8
DVD / CD			5		1		1	1			1				1	3		3		3		1		20
																								0
																								0
																								0
Power Point			1		1		3	5	1		1	3	1		5				5	5	3	5	1	40
GEOPDF (embedded coordinates)		5	3		5			3	3	3	5					5	5	3	3	3		3	3	52
PDF (non geo)	5			5	3		5	1		5		5	5	3	3	3		5	1		1		5	55
ARC Shape File	3		5	3		3			5	1	3							1						24
ERDAS IMG																								0
MrSID						1																		1
Web streaming		3																						3
JPEG		1				5							3	1		1	3					1		15
BMP																								0
GEOTIFF	1																							1
ADRG / CADRG														5							5			10
Skyline Terra Explorer																								0
Google Earth (KMZ)																								0
																								0
																								0
BOSS	4	5	5	5	5	5	5	4	3	5	3	4	5	4	3	2	5	5	3	3	4	5	5	97
You feel you support	4	5	5	5	5	5	5	5	5	4	4	4	4	4	3	5	5	4	3	5	5	5	5	104
How well Geo perceived	4	5	5	5	4	5	4	5	5	5	4	4	4	4	4	5	5	3		5	5	5	5	100
How did commander perceive	4	5	5	5	4	5	5	5	5	4	4	4	5	5	5	5	4	5		5	5	5	5	104
How did Planning staff perceived	4	5	5	5	3	5	4	4	5	4	4	4	4	4	5	4	5	5		4	5	5	5	98
How did Intel section perceive	4	5	5	5	5	5	5	4	5	5	4	4	4	4	5	4	5	3	5	5	5	5	5	106

Given the respondent chose the source, this is how they further described that source	Standard NGA maps TLM,JOG etc (RFP, CADRG ..)	CIB (1meter or 5meter)	DTED (level 0,1,2) and SRTM	vector feature data (VITD)	LIDAR (Light Detection and Ranging 1meter)	High Resolution EO (Buckeye, highlighter etc.)	Urban Tactical Planner (Shape files or TE fls)	Commercial Imagery	National Assets (NTM)	Any geospatial database (please list name/source)	
Multiple times a day	15	4	6	8	6	10	1	9	1	5	5
Once a day	2		2	1	2	2	2	1	2		4
Once a week	2	3	4	1	5	4	1	2	3	2	3
Once a month					1			1			2
Sum	19	7	12	10	14	16	4	13	6	7	
5 - Extremely critical, could not operate without it	11		2	5	5	5	1	8	1	4	5
4 - Very beneficial, a primary source	3	4	7	2	6	5	2	1		3	4
3 - helpful, needed to make good products	5		2	3	3	4		4	2		3
2 - useful but could have substituted other data sources		2	1			2	1		3		2
1 - marginally useful, only used because nothing else available		1									1
5 - Very Effective, never failed	7	4	5	2	2	3		2		1	5
4 - Effective, never frustrating	7	1	3	6	1	2	3	4	3	2	4
3 - Neutral, had some issues with getting data	3		2	2	8	7	1	5	3	4	3
2 - Marginally effective, significant issues to acquire data	2	2	2		2	4		2			2
1 - Not effective at all, not able to obtain desired data					1						1

	Standard NGA maps TLM,JOG etc (RFP, CADRG ..)	CIB (1meter or 5meter)	DTED (level 0,1,2) and SRTM	vector feature data (VITD)	LIDAR (Light Detection and Ranging 1meter)	High Resolution EO (Buckeye, highlighter etc.)	Urban Tactical Planner (Shape files or TE fls)	Commercial Imagery	National Assets (NTM)	Any geospatial database (please list name/source)
Ave	4.7	4.1	4.2	4.7	3.9	4.4	4	4.4	3.7	4.4
Std	0.2	0.4	0.3	0.2	0.3	0.2	0.5	0.3	0.4	0.4
Ave	4.3	3	3.8	4.2	4.1	3.8	3.8	4.3	2.8	4.6
Std	0.2	0.5	0.3	0.3	0.2	0.3	0.7	0.3	0.5	0.2
Ave	4	4	3.9	4	3.1	3.3	3.8	3.5	3.5	3.6
Std	0.2	0.6	0.4	0.2	0.3	0.3	0.3	0.3	0.2	0.3

The following section contains the free text responses from the survey as well as informal interview responses conducted during the research that contributed to the knowledge of the AGE current state architecture.

A. Survey Results from Officers (21A, 215D)

General Comments:

- My team served mostly as a planning tool, assisting in isolated events, and provided the Common Operational Picture (COP).
- I'm not surprised by the number of Hardcopy/ PPT/ PDF products. I would submit that we need to consider the staff process outside the Ft Leavenworth class room. Staff processes are driven by the XO's preferences up front and the CDR's requirements as a course correction. The XO's stamp on the staff's products is very specific to the organization, the personalities that cycle into the staff and the operational constraints and/or requirements (call it the operational flavor) that orbits the battle captain's desk. Hard copy and static PPT/PDF products are not just tangible documents that feed some fundamental tactile need of every staff officer. Hard copy products are also the lowest common denominator in terms of getting inside the cognitive process of an individual staff section in the upstream or collaborative process, as well as delivering a suitable product for organizational output (downstream) as defined by the XO first and nuanced by the CDR second. Hard copy and static PPT/PDF products snap shot a knowledge base in what can be an extremely dynamic environment.
- I usually measured my team by all three criterion you listed. # of products / saturation across brigade / the number of references I received from trigger pullers ("Chief, my buddy had this really cool….. He said I should come see you to get one of my own") It is extremely difficult to gauge the relevance of your production. A team can chew through a whole lot of trees and still deliver crap. Talking to trigger pullers is the easiest way to get a feel for your production.
- I would lay out recommendations and production times to them individually. As an example, when we jumped from [location] X to Y the XO mandated that each vehicle would have a route product in the vehicle. The S3 would determine additional information requirements to go on the product. I would return with an example product and a timeline to produce the requisite number of products. As time went on, (experience grew) those production times became noticeably shorter and shorter.
- Typical population of ABCS systems involved the "golden brick" solution. One master set of coverages were cut by my team and given to the ABCS contractors. They would populate the maps into a "golden brick" test the brick and then replicate all the other bricks from the golden bricks.
- Prior to publishing the master coverage to the contractors, the XO and S3 would receive a spread sheet from that detailed coverage size, file size, brick constraints, recommended scales by system age of each raster layer, and a graphic that showed the OE and graphic coverage. Once blessed, I did all the haggling with the contractors to ensure that the maps were delivered on time and worked as advertised. It took a few weeks to burn all the bricks.
- Average age of the tiles weren't always available. For the most part CIB1 was the most critical layer. If the Staff wasn't happy with the CIB1 coverage I would convert a newer commercial

image in to CIB1. I checked for errata by pulling tiles from the old CIB and comparing them to the new CIB. Keep in mind all of this was accomplished before the data went to the contractors. Updates were a major decision point for the staff. Any updates were accomplished via the golden brick method. (only for an extreme shift in the OE)

- 95% of the vector foundation was produced in house or QC'd from other teams and incorporated within our data set. For the most part all raster data originated from NGA. There were only a few occasions where a non standard map would be scanned and converted to RPF format as it was a high risk production that carried numerous caveats beyond the standard (do not use for targeting +). Those non-standard raster requirements were usually originated from the BN/SQDRN level.

What were the biggest AGE success stories:

- HLZ analysis, Sensor Placement LOS analysis, COP distribution, Route Studies
- IED plots in combination of using other 'INT' sections. This created GEOINT products for the command. It painted a clear and complete tactical picture with layers capable of turning on or off through Geo-PDF.
- The En BDE CDR and G2 worked together and placed the Geospatial Team under the G2and placed the NGA team under the operational control of me to synchronize Geospatial operations in the Corps. H also placed us in the SCIF next to the Imagery Analysts and we in effect had a GEOINT Cell. This gave me access to all of the information and expertise I needed to most effectively provide Geospatial Support to the Corps Commander and staff

What were the biggest frustrations:

- Lack of sufficient, standardized data (vector and raster); LIDAR files too large to do anything with; too many organizations distributing geospatial data/products/analysis
- Requesting stateside support for critical data from NGA, i.e. Soils.
- The proliferation of multiple contractor supplied battle command systems and the lack of a common foundation for information exchange and data standards. This caused me to convert products into various formats so that I could ensure all systems would be able to use my data and products. Also there were no methods to capture geospatial data from various organic sources within the Corps unless I manually hunted for them and jammed them into my database. For instance the C5 guys had a list of hospitals on a spread sheet with some information that I needed to fill in holes in my urban database. If I had not gone to them and discovered this spread sheet I would never have known about it. Many such examples happened throughout the operation.
-

B. Survey Results from noncommissioned officers (NCOs) (21Y)

General Comments:

- I just can't bring myself to say it, but PPT was a norm, but it was always a PPT of a JPEG map analysis to scale

What were the biggest AGE success stories:

- Updating our standard products an posting to a non-DTSS/GIS enabled web portal regularly
- The DTSS.
- The biggest success story was the fact that my Terrain team introduced a FOB's worth of units to the benefits of incorporating Geospatial products into their mission planning. We even had numerous units from other bases call or e-mail requests for products, which is how it should be. Geospatial data should be shared, not horded, by Terrain teams. Too many times we had someone come in to the shop and be extremely surprised that we would make a product for them, no matter where they were located or what unit they belonged to. Everyone that came into my shop, I educated them on the uses and benefits of different products and made every effort to show them ways they can access websites with products already made or contacts where they can ask for things that we did not make, though most times I ordered these myself. My shop consisted of 3 instead of the normal 4 people, one of which had no experience in this field. I was extremely proud of their efforts to produce products to my high standards. We had numerous comments and praise for the way our shop treated customers and for the high quality products we produced.
- The Ability to Post PDF products for any element outside our area to download for their mission support
- Arabic maps for ISF, Unit location maps for Staff sections
- Assisting a broad array units has allowed us to create products beyond the scope of our supported unit's tasking.
- Tracking and finding medivacs and down aircraft.

What were the biggest frustrations:

- 60% of our work is still pretty maps that people want because the customer saw it on someones's wall and they think they need it too. No matter how hard we tried to sell/educate the customer on our capabilities, they don't utilize us to full (technical) potential, though they will tax us with busy work. Skyline TerraSuite software is so powerful and enabling for the guys on the ground. Everybody thinks its cool, but nobody wants it. Wish that would change.
- Bandwidth/network. It seems that the military has data and technology that far exceeds its needs and is perfect because it allows us to be mobile, adaptive and agile for the fight. The issue always comes in moving all this great data.. So we find ourselves sitting on GB's if not TB's worth of data and are forced to try and get it threw a coffee straw to someone on the other end. Most of the time causing huge delays in passing information or failure to pass it because the network times out. With the new push for bans on external devices it has made it even more frustrating because you fight the S6 shops trying to drop a system from the network to plug up your TB drives of data that someone flies in to you or ships to you. The reality of the times is everything needs to be moving towards WMS services. The future of the geospatial community lies in its ability to create these products and have them posted to a web site/service so they can be quickly viewed, edited, downloaded, or printed by the end user. The other thing we noticed lacking is a central repository. When we got into Iraq in '07 the military on a whole had been doing planning/operations in

theatre for call it 5+ years. We found 7 different versions of the country border alone and not 1 person anywhere could be an authoritative decision maker on which boundary was accurate and should be used for all products, period. There was an attempt by the 100th topo under CW2 Stratton to stand up the IGD(Iraqi Geospatial Database). The intent was to ingest everything in theatre from corps, division and brigade levels with appropriate metadata and then force a standardization of the data and serve it back up to all in theatre via the IGD. Last I had heard that project fell apart somewhere around the end of 2008. I did recently learn that the NGA came along with their new CASI servers as a way to do something similiar but their focus is on ingesting non-standard data and making it available to everyone. So although somewhat effective at least for data sharing I have no direct experience with how easy/fast downloading data from those servers is. It also is lacking in that they have not yet determined anyway to force standardized metadata attributions of the incoming data or a way to help QA/QC data collected to turn back over and distribute as standardized data under a VITD/UTP style format or something similar in nature.

- The DTSS when it crashed.
- The fact that none of the geospatial servers in theater were operational except Divisions. What good was a server if no one but division had access to it? Division ended up posting things on their website so BDE teams could pull some data off but due to the file restrictions, these had to be pretty small. The biggest frustration was the USB ban. Another pet peeve of mine was the fact that most of the terrain teams in theater were on [in one place]. Data was not being disseminated down to the lower levels, specifically the battalion and company level. Most missions at those levels were still relying on the old NGA paper TLM's, which could be mass ordered with a DLA account, though we did re-print many of those for a quick fix if the mission was leaving that day. One last pet peeve was using the terrain teams as mass printers since we had a 42" and 36" plotter. Those not lucky enough to have a strong NCO in charge we used as printers. I had requests for things like printing targets for the range, printing family pictures and lastly CHARTS. I was constantly being asked, and then told at the end, to make charts and graphs for the Brigade Commander and XO. This is a waste and in my opinion, abuse of resources!
- The Ease of ordering supplies, Paper, Ink(Until Thumb Drives got banned then that impeded movement greatly)
- Some units have Terrain sections with s3/G3, others with S2/G2. Big army needs to make a decision if we will be part of the engineer community or the intel community. If we are going to be part of intel, (as is the trend for more units) 21Y needs to require a TS/SCI clearance.
- There is only one slot for a 21Y not equipment when I arrived had to order and collect all thing need to run a shop, maintain it all and try to convince the command that they need a geospatial analyst. Justify cost.
- Being seen by supported unit primarily as a S3/engineering asset; this seemed to limit the number of more analysis driven products.
- lack of research and product availability within CONUS.

C. Survey Results from enlisted Soldiers (21Y)

What were the biggest AGE success stories:

- COMMUNICTAION THROUGHOUT THE ENTIRE TERRAIN TEAM
- BEING ABLE TO PRODUCE VISUAL AIDS TO IMPORTANT MISSIONS AND BE THANK BY THE CUSTOMERS.
- providing analysis and infrastructure support to the corps of engineers for base improvement and development
- Created a "mapbook" of our entire AO. Gave to the Commanders of each company in digital format before deployment.

What were the biggest frustrations:

- ARC map crashing and malfunctions, not being able to print, not being able to get information off of DTSS to disseminate information, not having a server.
- TIME
- OLD SYSTEMS OPERATIONS
- Getting imagery needed for mission.
- lack of knowledge of geospatial capabilities by non geospatial MOS's.
- Lack of updated Useful Imagery/CADRG (TLM,JOG). Need more Buckeye!! More LIDAR!! Need maps that werent made 15 years ago. Update the VITD.
- Data Management after we took over.
- Most of the other soldiers in our unit didn't really know what we do. They confused us with a print shop and we always asked if we laminated things.

Appendix C: Enterprise Boundary System Dynamics Model

The following list contains the specifics of the system dynamics model that defines the AGE interface.

Each variable is explained in detail. The name of the variable is give, with the formulated equation for how the variable is calculated in the simulation. The units of the variable and the brief description are then provided. For more information about the structure of the model and how the model was developed, see the current state discussion of the model development.

(##) Name of model variable = equation for how variable derived in simulation
Units of the variable
A brief description of the variable with discussion as needed

AGE Model:

(01) BDE Terrain Team Geospatial Data Base= INTEG (Increase in Terrain Team GF-Decrease in Terrain Team GF,0)
Units: Dmnl
This is the utility of geospatial data contained in the Brigade terrain team.

(02) BDEGeospatial Foundation Data= INTEG (Increase in BDE GF-Decrease in BDE GF,0)
Units: Dmnl
This is the utility of geospatial foundation data for mission planning execution at the brigade level (used by the brigade commander and staff elements)

(03) BN Geospatial Foundation Data= INTEG (Increase in BN GF-Decrease in BN GF,0)
Units: Dmnl
This is the utility of geospatial foundation data for mission planning execution at the battalion level (used by the battalion commander and staff elements)

(04) Change of Mission=PULSE(330, 1)
Units: Dmnl/(Day/Dmnl)
The loss of utility of the geospatial foundation due to the operation changing locations or focus to the degree that the current data set does not build useful mental models

(05) Company CP Geospatial Foundation Data= INTEG (Increase in Company GF-Decrease in Company GF,0)
Units: Dmnl
This is the utility of geospatial foundation data for mission planning execution at the company level (used by the company commander and company headquarters and CP)

(06) Cumulative geo benefit= INTEG (increase to cumulative geo benefit,0)

Units: Dmnl*Day

This is the integral of the daily benefit from the geospatial foundation lay over time.

(07) data updates from higher=IF THEN ELSE(((RANDOM UNIFORM (0 , 1 , 500))>0.9) , RANDOM NORMAL(0 , 0.3 , mean benefit of updates,st dev of updates from higher, 1000) , 0)

Units: Dmnl/Day

The benefit of data received from a higher echelon during a deployment is approximated by a random value drawn from a normal distribution

(08) Decrease in BDE GF=BDEGeospatial Foundation Data/Time constant for degradation of GF+Change of Mission*BDEGeospatial Foundation Data

Units: Dmnl/Day

This is the loss of utility of geospatial information from the Brigade staff due to loss of latency (aging of the information) as well as change of mission (change in location or type of missions conducted)

(09) Decrease in BN GF=BN Geospatial Foundation Data/Time constant for degradation of GF+Change of Mission*BN Geospatial Foundation Data

Units: Dmnl/Day

This is the loss of utility of geospatial information from the BN staff due to loss of latency (aging of the information) as well as change of mission (change in location or type of missions conducted)

(10) Decrease in Company GF=Company CP Geospatial Foundation Data/Time constant for degradation of GF+Change of Mission*Company CP Geospatial Foundation Data

Units: Dmnl/Day

This is the loss of utility of geospatial information from the Company CP due to loss of latency (aging of the information) as well as change of mission (change in location or type of missions conducted)

(11) Decrease in Ind GF=Platform Indv Geospatial Foundation Data/Time constant for degradation of GF+Change of Mission*Platform Indv Geospatial Foundation Data

Units: Dmnl/Day

This is the loss of utility of geospatial information from the platform or individual level due to loss of latency (aging of the information) as well as change of mission (change in location or type of missions conducted)

(12) Decrease in Terrain Team GF=BDE Terrain Team Geospatial Data Base/Time constant for degradation of GF+Change of Mission*BDE Terrain Team Geospatial Data Base

Units: Dmnl/Day

This is the loss of utility of geospatial information from the Brigade terrain team due to loss of latency (aging of the information) as well as change of mission (change in location or type of missions conducted)

(13) Deployment time=15

Units: Day

This is the number of days from the deployment order until the information are packed and shipped. Therefore this is the number of days that the initialization of geospatial foundation can occur.

(14) Effectiveness of RIP TOA=1

Units: Dmnl

This is the percentage of geospatial foundation data that is passed to the new unit.

(15) Experiential GF data gap=Required GF benefit-Learned Environment Interaction Data

Units: Dmnl

The GF experience data gap is the difference of the information desired (assumed here to be complete knowledge initially) minus the information already learned threw experience

(16) FINAL TIME = 450

Units: Day

The final time for the simulation.

(17) fraction of ESS benefit filtered up=1

Units: Dmnl

This is the percentage of the information that is collected by Solider conducting operations that is available and implemented into the geospatial foundation layer. It is a value from 0 to 1.

(18) fraction of geospatial utility filtered down=0.5

Units: Dmnl

This is the percentage of data that is passed to the lower echelons. Data may not be passed based on bandwidth constraints, doctrinal reasons or other.

(19) GF Data Gap=

MAX(GF needs for Planning-BDEGeospatial Foundation Data,0)

Units: Dmnl

The Geospatial Foundation data gap is the difference of the GF needs for planning and the available GF. The GF needs for navigation are typically not felt by the GET due to the distance from the operators on the battlefield (they are not located at BDE staff level)

(20) GF needs for Planning= 1

Units: Dmnl

this is the perceived geospatial foundation needs that are articulated to the GET. If all needs are perfectly articulated than the value is 1. If no need is articulated than the value is 0.

(21) Increase in BDE GF=Initialization of GF+MAX(BDE Terrain Team Geospatial Data Base-BDEGeospatial Foundation Data, 0)/time to update GF from higher+Mission Experiences*fraction of ESS benefit filtered up

Units: Dmnl/Day

(22) Increase in BN GF=MAX(BDEGeospatial Foundation Data-BN Geospatial Foundation Data , 0)/time to update GF from higher+Initialization of GF+Mission Experiences*fraction of ESS benefit filtered up

Units: Dmnl/Day

The increase to the geospatial foundation data occurs as the sum of the initialization of the GF plus the incremental updates that come from the next higher echelon

(23) Increase in Company GF=MAX(BN Geospatial Foundation Data-Company CP Geospatial Foundation Data, 0)/time to update GF from higher+Initialization of GF+Mission Experiences*fraction of ESS benefit filtered up

Units: Dmnl/Day

The increase to the geospatial foundation data occurs as the sum of the initialization of the GF plus the incremental updates that come from the next higher echelon

(24) Increase in Ind GF=MAX(Company CP Geospatial Foundation Data-Platform Indv Geospatial Foundation Data , 0)/time to update GF from higher+Initialization of GF+Mission Experiences*fraction of ESS benefit filtered up

Units: Dmnl/Day

The increase to the geospatial foundation data occurs as the sum of the initialization of the GF plus the incremental updates that come from the next higher echelon

(25) Increase in Terrain Team GF=initial data provisions from higher+Terrain Team data generation+data updates from higher+Mission Experiences*fraction of ESS benefit filtered up

Units: Dmnl/Day

the utility of stored data is generated by the utility of data gained from above, below and generated internally.

(26) increase to cumulative geo benefit=Utility of data passed to new unit from BDE

Units: Dmnl

This is the total benefit each day from the geospatial foundation.

(27) initial data provisions from higher=PULSE(5 , 5)*0.05

Units: Dmnl/Day

This is a pulse function as data provisioning and synchronization is pushed from higher.

(28) INITIAL TIME = 0

Units: Day

The initial time for the simulation.

(29) Initialization of GF=IF THEN ELSE(PULSE(0, Deployment time) , (BDE Terrain Team Geospatial Data Base*fraction of geospatial utility filtered down)/Time to initial the GF , 0)

Units: Dmnl/Day

This is the GF data that is pushed down from BDE down the lower echelons in the initial data push following a deployment order or change of mission.

(30) Learned Environment Interaction Data= INTEG (Mission Experiences-Loss of Experience, 0)

Units: Dmnl

This is the captured experience from operations. It includes things like "this is the dangerous part of town, increase convoy force protection" and it is contained in data bases, notebooks and shared unit memory.

(31) Loss of Experience= Learned Environment Interaction Data*(Personnel Turnover+Change of Mission)+Learned Environment Interaction Data/Time constant for degradation of GF

Units: Dmnl/Day

This is the loss of experience in terrain either by the unit being reassigned to a different geographic location, or the personnel changing jobs and taking some (or all) of the experiential information with them (memory, notebooks, spreadsheets etc...)

(32) mean benefit of updates=0.003

Units: Dmnl/Day

This is the mean of benefit of new data received from higher echelons to the brigade terrain team

(33) Mission Experiences=IF THEN ELSE(PULSE(0 , Deployment time)<0.5 , Experiential GF data gap/OPTEMPO , 0)

Units: Dmnl/Day

The increase to understanding of terrain from the Soldier operating in a battlespace over time. This information is captured in several locations, "green books" spread sheets and just remembered experiences.

(34) OPTEMPO=220

Units: Day

This is the time it takes to acquire knowledge of terrain that develops by operating in a battlespace. The longer faster the OPTEMPO the shorter the time.

(35) Personnel Turnover=0

Units: Dmnl/Day/Dmnl

This is the rate at which personnel change over in their assigned duties

(36) Platform Indv Geospatial Foundation Data= INTEG (Increase in Ind GF-Decrease in Ind GF,0)

Units: Dmnl

(37) Required GF benefit=1

Units: Dmnl

Soldiers desire to know everything possible about their Area of Operations. For example, when arrive to a new area, the Soldiers typically will recon all areas within the AO, and then systematically learn as much as possible about the cities, towns, people and key terrain elements.

(38) SAVEPER = TIME STEP

Units: Day [0,?]

The frequency with which output is stored.

(39) st dev of updates from higher=0.04

Units: Dmnl/Day

This is the standard deviation of benefit achieved from products delivered from higher down to the BDE terrain team

(40) Terrain Team data generation=GF Data Gap/Time to produce needed products

Units: Dmnl/Day

The geospatial foundation data production is determined by the data gap over the time that it takes to fill the data gap. Measured in utility / day.

(41) Time constant for degradation of GF=50

Units: Day

The time it takes for the utility of information to degrade due to latency.

(42) TIME STEP = 0.125

Units: Day [0,?]

The time step for the simulation.

(43) Time to initial the GF=10

Units: Day

The time it takes to build and replicate the geo foundation throughout the BDE

(44) Time to produce needed products=200

Units: Day

This is the average time it takes for the terrain team to bridge the Geospatial Foundation data gap. Measured in days.

(45) time to update GF from higher= 40

Units: Day

This is the average time for utility at the higher echelon to deliver that benefit to the subordinate organization.

(46) Utility of data passed to new unit from BDE=(BDEGeospatial Foundation Data+BDE Terrain Team Geospatial Data Base+BN Geospatial Foundation Data+Company CP Geospatial Foundation Data+Platform Indv Geospatial Foundation Data +Learned Environment Interaction Data)*Effectiveness of RIP TOA

Units: Dmnl

At any point in time the total utility of geospatial foundation data that is passed during a relief in place / transfer of authority (RIP TOA) is the sum of the utility of geospatial foundation data within the terrain team and the brigade staff times a fraction based on the effectiveness of the RIP TOA process

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